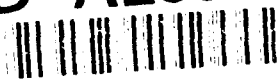


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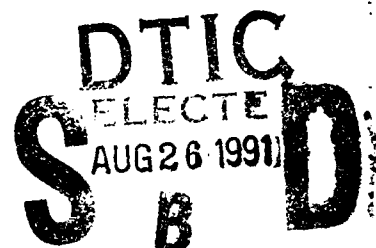
# AN ANNOTATED BIBLIOGRAPHY OF U.S. ARMY NATICK ANTHROPOLOGY (1947-1991)

By  
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Sarah M. Donelson  
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Geo-Centers, Inc.  
Newton, MA

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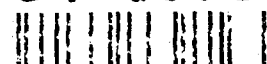
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## PREFACE

With 179 references covering a period of 44 years, this volume updates AN ANNOTATED BIBLIOGRAPHY OF U.S. ARMY ANTHROPOLOGY (1947-1977), prepared by Robert M. White in 1977. References represent the research of scientists associated with the U.S. Army Natick Research, Development, and Engineering Center.

U.S. Army anthropology and anthropometry are also done at other installations. Although we cannot claim an exhaustive bibliography such as we are providing for U.S. Army Natick research, we have included as many references as we could find for these other installations, listing them in a separate Appendix.

References represent a variety of publications. Covered are technical reports and memoranda, books, contract reports, journal articles, conference proceedings, magnetic data tapes, and papers presented at scientific meetings.

Section I of the bibliography contains the annotated listing of references. Here, each title is followed by a summary or abstract taken directly from the source whenever possible. To help researchers, key words are supplied for each listing, and these are indexed in Section II. Section III lists authors along with reference numbers of their publications, and Appendix I concludes with non-Natick references.

Thanks go to Ms. Brenda Baker, Dr. Claire C. Gordon, Mr. Steven Paquette, Dr. Kenneth Parham, and Dr. Robert A. Walker of U.S. Army Natick for their extensive editorial comments, as well as to Dr. Madeleine Hinkes of the Central Identification Labs, Ft. Shafter, Hawaii, for providing CIL-HI abstracts. The editorial assistance of Mr. Robert Woods of GEO-Centers, Inc. is also greatly appreciated.

Comments on this bibliography should be addressed to:

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Natick, MA 01760-5020

I. ANNOTATED LISTING OF U.S. ARMY NATICK PUBLICATIONS IN  
ANTHROPOLOGY

1947 PUBLICATIONS

- 1 Randall, Francis E., and Melvyn J. Baer. SURVEY OF BODY SIZE OF ARMY PERSONNEL, MALE AND FEMALE; PROJECT NO. E-59-46, PHASE I, REPORT NO. 1 — METHODOLOGY. Report No. 122, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, July 1947. 47 pages

KEY WORDS: Anthropometric Survey, Body Size, Body Type, Male Anthropometry, Measurement Techniques

The information presented in this report describes the measurement techniques utilized in an anthropometric survey of U.S. Army men carried out in 1946 by the U.S. Army Quartermaster Corps.

The field survey of the anthropometry of men began early in May, 1946, and continued at six different separation centers until November, 1946, with a total of 105,062 men being measured. Of the total measured, 96,381 were being separated from service, or were re-enlisting; 8,681 men were just entering the Army and had no previous military experience. Of the total 105,062 men, 6,404 were Black or Black-White mixture. Physical types were recorded photographically on 49,500 officers and enlisted men studied in the survey.

The actual techniques utilized in measuring the subjects are described and illustrated by photographs.

The data collected in this survey are considered adequate for use to establish specifications on the physical size of male military personnel for clothing sizing and tariffing, and for determination of space requirements of personnel. The data are also suitable for a study of the physical type and size of male military personnel in regard to function performed in military occupations and to provide bases for personnel selection and treatment in the future.

- 2 Randall, Francis E. SURVEY OF BODY SIZE OF ARMY PERSONNEL, MALE AND FEMALE; PROJECT NO. E-59-46, PHASE 4, REPORT NO. 1 — METHODOLOGY AND GENERAL CONSIDERATIONS (FEMALE). Report No. 123, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, July 1947. 36 pages

KEY WORDS: Anthropometric Survey, Body Size, Body Type, Female Anthropometry, Measurement Techniques, Occupational Activities

The information presented in this report concerns methods of measurement and general considerations of the population measured in an anthropometric survey of U.S. Army women carried out in 1946 by the U.S. Army Quartermaster Corps.

A total of 8,864 Army women were measured at three Army installations. Sixty-four standard anthropometric and tailoring dimensions were measured. Body build photographs were taken of 555 women at six Army General Hospitals. Of those measured, approximately 5,216 were WAC enlisted women and WAC officers, and 3,648 were Army nurses; 8,559 were White and 305 were non-White. All women measured had previous military experience.

Descriptions of the measurements and techniques utilized in the survey are presented in this report.

Preliminary analyses of the data on 8,258 U.S. born White women for age, weight, and stature have been made and are reported here. These data show that Army WAC enlisted women tend to be the shortest and lightest, WAC officers tend to be the tallest and heaviest, as well as the oldest, and Army nurses fall between the other two groups for stature and weight.

The entire series will provide basic information which will enable clothing and equipment designers to standardize the sizes of their products for use by Army women.

### 1948 PUBLICATIONS

- 3 Bullen, Adelaide K. VOCATIONAL INCIDENCE OF SEVEN BODY TYPES IN 547 U.S. ARMY WOMEN. Contract Report (Contract W44-109-QM-1078), Department of Anthropology, Harvard University, Cambridge, MA, May, 1948. 122 pages

KEY WORDS: Anthropometric Survey, Body Type, Female Anthropometry, Foot, Occupational Activities

The objective of this study is to determine whether there are distinct constitutional types of women who engage in particular types of military activities and whether there are any desirable selection procedures which might be utilized in the future for the benefit of the Armed Services.

Body build photographs of 547 WAC and Nurse volunteers in six Army General Hospitals were collected and analyzed, together with 38 anthropometric measurements on each subject.

There appear to be some distinct constitutional types of women who tend to engage in particular types of military activities according to the following seven major types of body build distinguished in this study: FAT (Endo), MUSCULAR (Meso), THIN (Ecto), MUSCULAR-FAT (Meso-Endo), MUSCULAR-THIN (Meso-Ecto), PLUMP-DELICATE (Endo-Ecto), and MODERATE MIXTURE.

Most occupational or other categories, although having MODERATE MIXTURES and THIN women as the leading types, show other distinct differences in trend when compared with each other. As to sizing tariffs, it is important to realize that MODERATE MIXTURES, who show no extreme tendency in body build, tend to be below average in size.

Means for the 38 measurements vary for the seven body types; these trends reflect the direction of the observational criteria for the seven body types. The seven body types show some differences in tendencies to disproportion, lumbar curve shape and placement of hip fat. Foot size and proportion tends to vary with body type. FAT women (relatively common in the Nurse group) tend to have comparatively small, plump feet which carry a heavy body weight.

- 4    Randall, Francis E. **APPLICATIONS OF ANTHROPOMETRY TO THE DETERMINATION OF SIZE IN CLOTHING.** Environmental Protection Series Report No. 133, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, June 1948. 108 pages

**KEY WORDS:**    Applied Physical Anthropology, Attenuation, Body Fat, Body Size, Clothing Sizing, Mathematical Methods, Muscle Development, Tariff Derivation

The contents of this report were designed to aid in the understanding of subject matter developed from the analysis of anthropometric data resulting from the survey of body size of male and female Army personnel. The objective of the report is to describe mathematical methods of interpretation of body dimensions for use in the determination of sizes and tariffs of clothing.

Data are presented which will serve to simplify the mathematical concepts involved in application of anthropometric data to clothing size and tariffing problems. An understanding of the contents of this report will aid clothing designers and supply agencies in the utilization of anthropometric data in their respective problems.

- 5    Hooton, Earnest A. **BODY BUILD IN RELATION TO MILITARY FUNCTION IN A SAMPLE OF THE UNITED STATES ARMY.** Contract Report (Contract W44-109-QM-1078), Department of Anthropology, Harvard University, Cambridge, MA, September 1948. 241 pages

**KEY WORDS:**    Attenuation, Body Fat, Body Type, Male Anthropometry, Muscle Development, Occupational Activities, Somatotype

The purpose of the present report is to describe the body type (somatotype) composition of a series of United States soldiers studied in the anthropometric survey conducted by the Quartermaster Corps and to make "special group analyses to indicate whether or not there are distinct constitutional types of men and women who engage in particular military activities." The scope of the present report is limited to the distribution of body types among the males and military and civilian sociological correlates of these types.

The material is a series of 31,658 Whites and 3,051 Blacks. The sample studied represents males accepted for military service, not the total U.S. male population of military age. Since the series was measured in the spring of 1946 and includes 85.53 percent of men who have served 24 months or less, it is clear that it hardly represents, as a whole, seasoned combat veterans. Many of the men must have been inducted in the later wartime drafts.

Body type classification is based upon the study of front, back, and side views of the nude individual, together with data on the relation of height to weight. Three structural body components are considered in the classification: fat development, muscle development, and degree of attenuation or elongation as expressed by the index of height/cube root of weight. Each component is graded on a scale from 1 to 7, by morphological examination in the case of fat and muscle, and by dividing the total range of the height/cube root of weight index into seven equal steps in the case of the third component which grades attenuation. The total body type of the individual is expressed by a three-digit combination, each digit ranging from 1 to 7. Thus, 1-1-7 indicates a body type of minimum fat development, minimum muscle development, and maximum attenuation, or height relative to weight. 4-4-4 indicates an individual at approximately the middle of the range of fat, muscle, and attenuation. These types, numerically designated, are lumped into 18 groups, each containing closely similar types, for purposes of correlation with military specialty and with other sociological phenomena.

- 6 Hooton, Earnest A. **ALBUM ILLUSTRATING BODY BUILD IN RELATION TO MILITARY FUNCTION IN A SAMPLE OF THE UNITED STATES ARMY.** Contract Report (Contract W44-109-QM-1078), Department of Anthropology, Harvard University, Cambridge, MA, September 1948. 56 pages

**KEY WORDS:** Attenuation, Body Fat, Body Type, Male Anthropometry, Muscle Development, Occupational Activities, Somatotype

This album illustrates the report **BODY BUILD IN RELATION TO MILITARY FUNCTION IN A SAMPLE OF THE UNITED STATES ARMY.** The photographs follow the order of body build subgroups listed in Table 1, page 12, of the report. Each photograph is labeled with the name of the body type subgroup, the numerical designation by components of the specific body type (e.g. 1-1-7), and the classification as to service utility (Combat, General Utility, or Service Type) according to Table ii, page xxi of the report. In general, the ordering of the photographs follows that of increasing development of the first structural component (fat), and second structural component (muscle). This involves also increasing values of the third or attenuation component within each subgroup, but a general decrease of attenuation (elongation) through the series of subgroups.

A few of the rare and numerically unimportant body types have been included in the illustrations, in order to suggest the wide range of individual body types in the series.

The photographs of the Black Series, which follow those of the Whites, are ordered in the same manner. Preceding these illustrations is a table of Total Distribution of Body Type Subgroups in the Black Series.

- 7 Randall, Francis E. ANTHROPOMETRY IN THE QUARTERMASTER CORPS.  
American Journal of Physical Anthropology, N.S. Vol. 6, No. 3,  
373-380, September, 1948.

KEY WORDS: Anthropometry, Applied Physical Anthropology, Fit Test,  
Measurement Techniques

The entry of anthropologists into military research, in the engineering sense, furthered a new field of endeavor which has come to be called Applied Physical Anthropology. It is the purpose of this paper to give a somewhat broader picture of the Army program and to attempt to describe how anthropometry as a field of endeavor fits into the organization of military research. The application phases fall into two main categories. The first is, to a great extent, pure anthropometry in that it is concerned with the measurement of human beings in considerable detail. The collection of large series of detailed measurements is considered to be of primary value in that the data, when analyzed, will serve to provide a constant source of reliable information upon which further studies may be based. The second phase falls into the category of testing. In this phase, anthropometry is highly specialized in that small numbers of dimensions are taken and quite frequently taken on limited series of individuals which are subsequently evaluated in terms of the initial large series.

This paper, although confined to a brief review of methods of application of anthropometry to military problems, should indicate that there is a very real place for the applied physical anthropologist, not only in military fields of endeavor, but also in all types of industry concerned in the design, development, and fabrication of equipment destined for use by the human being. This situation, only beginning to be realized by responsible personnel in industry, presents a definite challenge to physical anthropologists to produce properly trained personnel who may be equipped to continue the many ramifications of the application of physical anthropology to the comfort and well-being of other people.

### 1949 PUBLICATIONS

- 8 Randall, Francis E. **ANTHROPOMETRIC NOMOGRAPH OF ARMY MEN.**  
Environmental Protection Section Report No. 147, U.S. Army  
Quartermaster Climatic Research Laboratory, Lawrence, MA, January  
1949. 20 pages

**KEY WORDS:** Anthropometric Nomograph, Chest Circumference, Key  
Dimensions, Male Anthropometry, Stature

The purpose of this report is to provide a simple source of reference of anthropometric data for use by designers of clothing and other personal equipment.

An analysis of the Army population has been made in order to present the interrelationships which exist between 24 bodily dimensions and 2 independent bodily dimensions, stature and chest circumference.

Resulting from this analysis is a nomograph from which can be easily read the average values of the 24 dependent dimensions which will be associated with any selected pair of stature and chest circumference values.

Use of this nomograph will be of aid to the designers and developers of clothing, personal equipment, and other equipment used by Army men.

- 9 Randall, Francis E., and Ella H. Munro. **ANTHROPOMETRIC NOMOGRAPH of ARMY WOMEN.** Environmental Protection Section Report No. 148, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, February 1949. 13 pages

**KEY WORDS:** Anthropometric Nomograph, Cervicale Height, Female Anthropometry, Hip Circumference, Key Dimensions

The purpose of this report is to provide a simple source of reference of anthropometric data for use by designers of women's clothing and other personal equipment.

An analysis of an Army female population, 18 to 29 years of age, has been made in order to present the interrelationships which exist between eight bodily dimensions and two independent bodily dimensions, cervicale height and hip circumference.

Resulting from this analysis is a nomograph from which can be easily read the average values of the eight dependent dimensions which will be associated with any selected pair of cervicale height and hip circumference values.

This nomograph will be of aid to the designers and developers of clothing, personal equipment, and other equipment used by Army women.

- 10 Randall, Francis E., and Ella H. Munro. **REFERENCE ANTHROPOMETRY OF ARMY WOMEN.** Environmental Protection Section Report No. 149, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, March 1949. 247 pages (Oversize Format)

**KEY WORDS:** Bivariate Tables, Female Anthropometry, Regression Analysis

The purpose of this report is to provide reference data on the anthropometry of Army women, both Women's Army Corps and Army Nurse Corps, for use by the designers of equipment and clothing intended for use by women in the Army.

One hundred and nine regression tables and 98 bivariates have been prepared to indicate a wide variety of interrelationships of pairs of dimensions which exist in a sample women's population in the Army. These data will serve as a guide to the designers of equipment for use by Army women.

- 11 Randall, Francis E. **ANTHROPOMETRIC NOMOGRAPH OF ARMY MEN.** (Paper presented at the 18th annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, April, 1949). American Journal of Physical Anthropology, N.S. Vol. 7, No. 2, 280, June 1949.

**KEY WORDS:** Anthropometric Nomograph, Chest Circumference, Key Dimensions, Male Anthropometry, Stature

In order to reduce anthropometry of Army men to the simplest form for use by non-scientific personnel, a nomograph has been prepared to demonstrate the relationships of 24 other dimensions to stature and chest circumference. This graph is based on a series of 24,500 U.S. Army separatees. [Abstract]

- 12 Randall, Francis E. AGE CHANGES IN YOUNG ADULT ARMY MALES. Human Biology, Vol. 21, No. 3, 187-198, September 1949.

**KEY WORDS:** Age Changes, Age Groups, Body Dimension Changes, Growth, Male Anthropometry, Skeletal Growth, Soft Tissue Changes

We have become so accustomed to thinking of growth as being a process which is involved in the production of the adult that it is extremely difficult to define properly the terminology which should apply to changes which occur after the individual has reached a stage commonly referred to as adult. Adulthood, in itself, is subject to a wide variety of interpretations, in that physiological, psychological, and physical fulfillment may be attained at widely divergent chronological periods.

The length of time beyond age 17 during which increases still occur which may be related to growth has not been clearly demonstrated. How much effect, for instance, does the failure of the vertebral epiphyses to close until age 25 have on the stature of men? Or, disregarding epiphyseal union, when is the maximum stature of American males attained? Is it statistically sound to compare a group of young adults between ages 20 and 24 with another group between 22 and 26 years of age? Once adult stature is reached, is there a period of stability maintained during which it is possible to group young adult males into age groups which would make them mutually comparable? The importance of these questions to the study of human biology is obvious. Would, for example, young men of ages 17, 18, and 19 have the same distributions of bodily dimensions as would young men of ages 20, 21, and 22?

In order to answer the questions posed above, a population of young men was studied. The total series consisted of 17,341 Army men, distributed over the entire United States in close approximation to the manner shown in the U.S. Census Report for 1940. In this series there were approximately 3,000 each of ages 17, 18, and 19; 1,500 of ages 20 and 21; and 1,000 of ages 22, 23, 24, 25, and 26. Owing to the wide distribution over the United States, and to the medical acceptability of the men involved, insofar as the Army was concerned, the series may be considered representative of the healthy American White male adult to a great extent.

All the dimensions studied show changes between 17 and 26. All except one show a positive increase, with inseam being the only one to show a decrease. The greatest change, as might be expected, occurs in weight, which increases from 139.26 pounds at age 17 up to 157.87 pounds at age 26. Next, as also might be expected, is the waist circumference, which increases from 73.2 cm at 17 to 79.2 cm at 26. Chest circumference is not far behind, increasing from 87.6 cm to 93.4 cm between 17 and 26.

Changes which are basically a result of body growth show a somewhat different picture. Stature reaches its maximum, in this series, at age 23, 175.1 cm. Even though the mean values indicate maximum attained at age 23, there is no statistically significant change after age 18. Consequently, evidence is strong that the American White male attains his adult stature, as an average, in the 18th year.

It should be clear that we are dealing with a range of years over which some portions of the body have ceased growth, while others are still involved in increase in dimension, even though we may not fully agree on terming this increase growth. Since the increase is open to question in its definition, the logical conclusion must be that the definition of growth must come under new consideration. Certainly the difference in the terms of increase in dimension and growth is subtle, but this very subtlety must be realized before clarification of the terms can be attained. One possible way out of this dilemma is to segregate the concepts into two categories: the cessation of skeletal growth as defined by the closure of epiphyses, and the cessation of growth or increase in dimension of the soft tissues. One objection to this type of consideration is that increasing age, decrease of muscular tonicity, and physical conditioning may all be contributory to a change in dimension which is not a result of growth. Waist circumference would be notable in this respect.

From the standpoint of the human biologist, the variability of successive age groups should certainly serve as a warning to exert extreme care in the weighting of populations for comparative purposes. A common practice, for example, has been to group series into five-year periods, 20-25, 25-30, 30-35, etc., which on the surface appears quite acceptable. However, if the proportions of ages within the subgroups differ to any marked degree, highly spurious results may be expected.

- 13 Hooton, Earnest A. MEASUREMENTS OF BODY BUILD IN A SAMPLE OF THE UNITED STATES ARMY. Contract Report (Contract W44-109-QM-2014), Department of Anthropology, Harvard University, Cambridge, MA, October 1949. 304 pages

KEY WORDS: Body Type, Chest Circumference, Key Dimensions, Stature

In the report of September, 1948 (Body Build in Relation to Military Function in a Sample of the United States Army), attention was devoted to: (1) the general distribution of body types classified into 18 groups; (2) the military utility of each of the several groups; and (3) the correlations of the body build groups with all sociological and other data compiled in the survey.

The present report deals with the more important measurements gathered on individual soldiers during the course of the survey, as such measurements apply to the various body types previously determined from the photographs.

Previous work on the metric data deals with separate measurements and combinations of measurements, but is not correlated with the individual body types as studied in this section of the survey. Consequently, this report analyzes some of the more important measurements, showing the extent to which they change with shifts of the three structural bodily components in the many body types recognized. It further takes each body type with a sample large enough for analysis and compares it as a metric entity with certain other adjacent or morphologically similar types. It discusses also the detailed distribution of body groups and types in relation to stature and chest girth. Thus the report of this year supplements and completes that of the preceding year in giving the precise metric descriptions of the body builds which had been summarily classified and related to various facets of military or sociological interest.

- 14 Randall, Francis E. **ANTHROPOMETRIC NOMOGRAPH OF ARMY WHITE MEN.**  
Human Biology, Vol. 21, No. 4, 218-232, December, 1949.

**KEY WORDS:** Anthropometric Nomograph, Anthropometric Survey, Chest Circumference, Key Dimensions, Male Anthropometry, Regression Analysis, Stature

The nomograph is a tool which is much more familiar to the physical sciences of chemistry, physics, and engineering than it is to the biological sciences. This is probably because multiple variables are much more commonly used in the experimental phases of those sciences. However, with the extension of physical anthropology into applied fields, it is logical that the development of nomographs and their use will facilitate the engineering uses of anthropometry. The usual presentation of anthropometric data in terms of means, modes, medians, standard deviations, etc., quite often fails to present a total picture of the physical dimensional characteristics of a population. A much more descriptive picture might result if the dimensions, related to at least two independent variables, could be presented in terms of space and direction, rather than by cold, dry numbers.

In order to determine accurately the multiple regression equations which are necessary in the preparation of a nomograph, a population of considerable size is required. In the particular case under discussion, a series of 24,500 male, White Army separatees was used. This series is large enough to permit a nationwide distribution representative of the

population. Further, this sizeable population permits an adequate definition, and thus may serve as a base reference for future nomographic comparisons. Twenty-five body measurements, together with two dimensions collected on a smaller series, are included in the analysis.

The first step in the preparation of the nomograph is the selection of the two independent variables. Fortunately, in this case, the matter is simplified by the fact that the engineering application and the biological usage involve the same two, stature and chest circumference. Stature is all-inclusive of length, and chest circumference tends to include girth as affected both by the skeleton and soft tissues. The second step is the preparation of a series of distributions of dimensions for each of several incremental categories of stature and chest circumference. This step is not actually required, but is advisable in order to have experimental observations available to check the accuracy of the equations.

The third step is the calculation of regression equations showing the regression of a variable on stature and chest circumference. Concurrent with the third step is the calculation of the standard error of estimate of the regression. Finally, having determined the regression slopes and shapes, the basic data can be used to locate the lines of relationship on the nomograph.

With a nomograph at hand, several facts may be directly assessed.

- (1) The proportionate degree of correlation of a dependent variable to each of the independent variables. Those dimensions which lie closer to stature than to chest circumference are more highly related to stature than to the girth. The opposite is, of course, true for those lying closer to chest circumference.
- (2) A vertical line for the dimension indicates linear regression on both independent dimensions.
- (3) Dimensions between stature and chest are positively related to both.
- (4) Those dimensions to the left of stature decrease with increase in chest girth, and those to the right of chest circumference decrease with increase in stature.
- (5) A dimension sloping up and to the right, but straight, is linear in its regression on stature, but curvilinear in its regression on chest. A slope to the left, progression upwards, would be the reverse.
- (6) A curved line indicates a curvilinear regression on both independent variables.

The nomograph then provides a pictogram of a complex of variables, which may be subjectively studied to indicate generally the inter-relationships present. Objectively studied, either as a nomograph or as a series of equations, measures of likenesses or differences within and between populations may be determined.

### 1950 PUBLICATIONS

- 15 White, Robert M. FRANCIS EUGENE RANDALL, 1914-1949. American Journal of Physical Anthropology, N.S. Vol. 8, No. 1, 113-117, March 1950.

**KEY WORDS:** Biography, Obituary, Randall, Francis E.

Francis E. Randall lost his life in the crash of a commercial airliner at Washington, DC on November 1, 1949. At the time, he was on official travel in connection with his duties as the senior anthropologist in the U.S. Army Quartermaster Corps.

Following undergraduate and graduate work at Western Reserve University in Cleveland (B.A., 1936 and M.A., 1938), Randall completed further graduate work in biology and anthropology at Harvard University and received a Ph.D. degree in 1942. During World War II, he was engaged in anthropological research and human engineering in the Army Air Forces at Wright Field, Dayton, Ohio.

In 1946, Randall began his work in the Army Quartermaster Corps, where he organized and directed the large anthropometric survey of U.S. Army men and women who were measured at separation centers at the end of the war. He then carried out the processing and analyses of the anthropometric data from this survey, and published some twelve major technical reports on the results of this work before his untimely death at the age of 35 years.

- 16 White, Robert M. A SUMMARY OF PRESENT RESEARCH IN ARMY ANTHROPOMETRY. (Paper presented at the 19th annual meeting, American Association of Physical Anthropologists, Boston, MA, April 1950). American Journal of Physical Anthropology, N.S. Vol. 8, No. 2, 272, June 1950.

**KEY WORDS:** Anthropometry, Clothing Sizing

Present research in Army anthropometry is summarized and some of the methods currently in use are indicated. Data available for investigation consist of measurements on over 100,000 men and 9,000 women, obtained during an anthropometric survey of Army personnel in 1946, as well as several smaller series measured subsequently. Since one of the primary responsibilities of the Office of the Quartermaster General is to clothe Army men and women, applications of anthropometric data to clothing problems have received first consideration. However, the Army program of research in physical anthropology may be considered to include both basic

research and practical applications. Various problems such as age changes, and physical changes resulting from the military environment are being investigated. Since the aim of the Quartermaster Corps with respect to clothing is to fit the Army population with the best possible clothing in a minimum number of sizes, requiring the least amount of alterations, the applications of anthropometry to studies of clothing sizes, size systems, and tariffs are particularly useful. Applications of anthropometry to clothing consist of relating body dimensions to clothing sizes. This has necessitated a metric definition of the Army population, together with the establishment of frequency distribution curves for various body measurements. Practical applications of anthropometry and statistics are thus possible in the essentially artistic field of clothing. [Abstract]

### 1951 PUBLICATIONS

- 17 Hooton, Earnest A., Frederick L. Stagg, Natalie B. Stoddard, and Emma H. Robbins. HANDBOOK OF BODY TYPES IN THE UNITED STATES ARMY (WHITE MALES). VOLUME I — DESCRIPTION OF TYPES; VOLUME II — PLATES. Contract Report (Contract W44-109-QM-2241), Department of Anthropology, Harvard University, Cambridge, MA, January 1951. Volume I — 311 pages; Volume II — 97 pages.

**KEY WORDS:** Anthropometric Survey, Body Fat, Body Type, Handbook, Male Anthropometry, Muscle Development, Occupational Activities, Racial Variation, Somatotype

This manual of body types in the United States Army is based upon the study of some 39,376 White male separatees measured and photographed in 1946 at six separation centers by anthropometric teams under the direction of the late Dr. Francis E. Randall, then Chief Anthropologist, Research and Development Branch, Office of the Quartermaster General. More than 100,000 men were measured; nearly 50,000 were photographed in three positions for the determination of body build type.

The classification of body types from photographs and measurements and the relationships of body types to various classes of information secured on each individual were undertaken by the Laboratory of the Department of Anthropology at Harvard University.

The first report of the Laboratory was submitted in September 1948 (Body Build in Relation to Military Function in the United States Army). This report dealt with the total distribution of body types in the sample of some 40,000 soldiers and the relation of body build to age, length of service, birthplace, national extraction, rank, military unit, military specialty, civilian occupation, education, marital status, and religious affiliation. The material was classified into types fit for combat duty and those fitted for service duties on the basis of the actual finding of excesses and deficiencies of the various types in categories of military function. In addition to White males, a series of some 3,000 Negro male separatees was similarly studied and figured in the report.

The second report of the Laboratory of Anthropology was submitted in October 1949 (Measurements of Body Build in a Sample of the United States Army). This report was concerned mainly with the statistical elaboration of the measurements of each body type sufficiently represented in the sample. Comparisons of the metric characters of the numerous body types were made, and corresponding body types in Blacks and Whites were discussed with the objective of clarifying racial differences.

To this end, the method of procedure in body typing has first been described. Then some 44 different body types are delineated in outline form with specific statements regarding body relief, fat covering, and the prominence of superficial muscles for each of the four main regions used in determining body type.

In order to facilitate the study of the descriptive outline of each type with reference to the illustration of that and other types, the album of plates is bound separately from the text. Again, each type selected is reproduced twice, forming two separate series of plates. The first series starts with the lowest value (grade 1) of the first component (fat) and illustrates the types in order of increases in the second component. Then the second and subsequent grades of the first component are shown in the same order. In the second series, the photographs are arranged by the second component (bone and muscle development) in sequence of increases in the first component. Thus, the reader can compare the body types in two ways.

- 18 Randall, Francis E., Ella H. Munro, and Robert M. White.  
ANTHROPOMETRY OF THE FOOT (U.S. ARMY WHITE MALE). Environmental Protection Section Report No. 172, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, January 1951. 25 pages

KEY WORDS: Anthropometric Nomograph, Foot, Footwear, Fort Knox Foot Survey, Key Dimensions, Lasts, Male Anthropometry

The purpose of this report is to provide data on the interrelationships of dimensions of the U.S. Army White male foot for use by designers of Army lasts and footwear.

Data obtained during an anthropometric survey of the feet of 5,575 Army White men are available in a report published in 1946 by the Armored Medical Research Laboratory, Fort Knox, Kentucky. Although the original report contains many useful data, the interpretations thereof do not permit direct application by designers of lasts and shoes for the Army. In order to provide greater detail and also more directly applicable information, an intensive analysis of the original Fort Knox data has been carried out.

The present practice of sizing and fitting shoes on the bases of foot length and ball breadth horizontal is not the best method available from a statistical point of view. A better method would be the use of ball length and ball girth dimensions, which most accurately control the fit of the shoe because of closer interrelationships with other critical dimensions of the foot. Reference data are provided in the form of tables and a nomograph for application of these relationships in the construction of lasts and shoes.

The general conclusion reached is that the dimensions of the foot which are closely related to the two basic dimensions, ball length and ball girth, are easily accommodated, whereas those poorly related cannot be accommodated by adjustment and, therefore, must be provided for in the design of the shoe. Dimensions which probably are critical in the proper fit of shoes, and which show low correlations with ball length and ball girth, namely, the dorsal and plantar arch heights, foot flare, and angular orientation of the heads of metatarsals, may be expected to occur with almost as much variation for any one size as they occur in all feet. Thus, in order to obtain shoes which will fit properly, it will be necessary to construct them in such a manner as to provide for a considerable amount of independent variation in most of the dimensions studied.

The results of this analysis provide a scientific basis for re-analysis of lasting practices.

- 19 White, Robert M., and Gerald Winston. A NINE-SIZE SYSTEM FOR FUNCTIONAL CLOTHING. Environmental Protection Section Special Report No. 50, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, April 1951. 16 pages

KEY WORDS: Clothing Sizing, Cold Weather Clothing, Male Anthropometry

Several alternative proposals for a nine-size system of cold-weather functional clothing have been evaluated with reference to available stature and chest circumference measurements of a large series of U.S. Army men. This investigation resulted in the development of a nine-size system which reflects the relationships indicated by body measurements and at the same time provides adequate coverage for the military population.

- 20 Newman, Russell W. CRANIAL CHANGES IN A SEQUENTIAL SKELETAL SERIES. (Paper presented at the 20th annual meeting, American Association of Physical Anthropologists, Ann Arbor, MI, March, 1951). American Journal of Physical Anthropology, N.S. Vol. 9, No. 2, 237, June 1951.

KEY WORDS: Archaeology, California, Cranium, Histograms, Male Anthropometry, Secular Trends

Comparisons of cranial measurements and indices of adult males from three archaeological horizons of Central California are illustrated by means of histograms. The visual analysis gained by this method gives insight into trends from horizon to horizon that are difficult to detect

by the standard statistical analysis. It is concluded from an inspection of trends that the maximum change occurred between the first two of the three sequential time periods, a conclusion not apparent in the tabulated statistics of the same material. [Abstract]

- 21 White, Robert M. **ANTHROPOMETRY AND CLOTHING SIZING.** (Paper presented at the 20th annual meeting, American Association of Physical Anthropologists, Ann Arbor, MI, March, 1951). American Journal of Physical Anthropology, N.S. Vol. 9, No. 2, 242, June 1951.

**KEY WORDS:** Anthropometry, Bivariate Tables, Clothing Sizing, Functional Jacket, Key Dimensions

There are four main fields in which the techniques and procedures of physical anthropology may be utilized in connection with military problems. Anthropometric data may be used in developmental work on military clothing and equipment, in investigations of body types in the military population, in identification of war dead, and in the development of prosthetic devices for war casualties. In the Army program of research in physical anthropology, anthropometric data have been used primarily in work on military clothing.

The development of a theoretical system of sizes for a functional jacket may be used as an example of the applications of anthropometric data in this type of work. Stature and chest circumference are selected as the controlling dimensions. Basic reference data are in the form of a bivariate chart showing the distribution of values of these two dimensions in the military population.

With assumed tolerances of three inches in each size, a size system of 25 sizes will be necessary to accommodate 15-inch ranges of stature and chest circumference in the military population. The number of sizes may be reduced to 16 or 15 by increasing tolerances in each size.

The correct location of the size system with respect to the distribution of body measurements in the population is determined by the ranges of stature and chest circumferences to be covered, together with the relationship between the two dimensions. The result is a system of nine sizes which fulfills the basic requirement of maximum coverage of the population with a minimum number of sizes. [Abstract]

- 22 Newman, Russell W. **CHANGES IN BODY DIMENSIONS DURING BASIC TRAINING IN RELATION TO CLOTHING SIZES.** Environmental Protection Section Report No. 176, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, August 1951. 27 pages

**KEY WORDS:** Basic Training, Body Dimension Changes, Clothing Sizing, Male Anthropometry

This study was initiated to investigate body dimension changes which take place in young men subjected to a rigorous military environment for the first time. These changes, as defined in terms of nude body measurements, have been analyzed in relation to clothing requirements for these men during the course of their basic training.

Five girth dimensions, waist, seat (hip girth), chest, shoulder, and neck, showed the greatest amount of change and were analyzed in detail. It has been shown that a sizable percentage of men change their girth dimensions sufficiently during basic training to require alterations on garments sized to their pre-training girths. These changes were shown to be largely assignable to men who were either small or large, and each group showed a definite trend in opposite directions; the small men tended to gain and the large men tended to lose. Fortunately, this allowed for a statistical analysis which differentiated and predicted girth changes with a reasonable degree of accuracy.

The most logical approach to the problem of sizing men entering the Army is to predict girth changes by means of data collected on men undergoing basic training and allow for these changes in the initial fitting. The limitations of such data were discussed, but it was evident that for all their limitations they represented an anthropometric estimate that should be preferable to not taking possible changes into account.

- 23 Newman, Russell W., and Robert M. White. **REFERENCE ANTHROPOMETRY OF ARMY MEN.** Environmental Protection Section Report No. 180, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, September 1951. 176 pages (Oversize format)

**KEY WORDS:** Bivariate Tables, Male Anthropometry, Regression Analysis

The purpose of this report is to provide data on the anthropometry of U.S. Army White males for use by the designers of equipment and clothing intended for men in the Army.

Eighty-seven regression tables and seventy-eight bivariate charts have been prepared to indicate a wide variety of interrelationships of pairs of dimensions which exist for a sample population of men in the Army. These data will serve as a guide to the designers of equipment for use by Army men.

- 24 Randall, Francis E., and Melvyn J. Baer; edited and revised by Russell W. Newman and Robert M. White. **SURVEY OF BODY SIZE OF ARMY PERSONNEL, MALE AND FEMALE — METHODOLOGY.** Environmental Protection Branch Report No. 122 (Revised), U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, October 1951. 48 pages. Originally published July 1947.

**KEY WORDS:** Anthropometric Survey, Body Size, Male Anthropometry, Measurement Definitions, Measurement Techniques

Descriptions and illustrations of anthropometric measurements collected on 105,062 men at six Army separation centers in 1946 are presented. The anthropometric survey was carried out to collect data on body dimensions of Army personnel for use in research on items of Quartermaster clothing and equipment. The data collected in this survey were considered necessary in the establishment of specifications on the body size of male military personnel, both in relation to clothing sizing and tariffing, and in the definition of workspace requirements.

This report was initially issued in July, 1947. The demand for it exhausted the supply; therefore, it was revised and reissued to coincide with the publication of Environmental Protection Section Report No. 180, Reference Anthropometry of Army Men. The changes consisted of the addition of one figure and expansion of the glossary. The photographs illustrating the measurements are the same, but definitions of some of the measurements have been clarified.

- 25 Trotter, Mildred, and Goldine C. Gleser. **TRENDS IN STATURE OF AMERICAN WHITES AND NEGROES BORN BETWEEN 1840 AND 1924.** (Contract DA44-109-QM-199, Department of Anatomy, Washington University, St. Louis, MO). American Journal of Physical Anthropology, N.S. Vol. 9, No. 4, 427-440, December 1951.

**KEY WORDS:** Age Changes, Long Bones, Racial Variation, Secular Trends, Skeletal Biology, Stature, Terry Collection

The average stature of an adult population may not remain stable from generation to generation. Environmental conditions, genetic composition and natural selection are among the many factors which can contribute to change. These factors have been grouped under the general term of secular factor as differentiated from the ageing factor which produces changes in stature during the life cycles of the individuals comprising the population. In studies of the effect of the secular factor on maximum stature, at least three methods, each with variations, have been applied. The average statures of living subjects at various age levels have been obtained and the trend, if any, observed; unfortunately, by this method, the effects of both the secular and ageing factors are included. Records

of average statures of previous generations have been compared with those of more recent or of present generations; by this technique the completeness of data of the previous generations cannot be controlled, and differences in the methods of taking the measurements may be unduly large. Finally, stature measurements of groups of school children of given ages in two or more successive periods have been compared; such data generally do not cover a very long time span.

The purpose of the present study is to offer supplementary data bearing on the question of the effect of the secular factor on maximum stature of individuals born in successive decades. To this end, the length of long bones, a measure which is closely related to maximum stature, is introduced as additional evidence.

Trends in stature have been studied in individuals (both sexes of American Whites and Negroes) born between 1840 and 1924. Two sources are represented: the Terry Collection with individuals born chiefly in the nineteenth century, and military personnel born in the twentieth century. In addition, the combined lengths of femur and tibia have been examined in relation to successive time periods.

There obtains a relatively constant average stature devoid of trend for all four groups born between 1840 and 1895. There is a tendency for the Negroes (both males and females) to increase slightly in stature from 1895 to 1905. A significant increase in male stature is present in individuals born between 1905 and 1924 (data for Negroes are less conclusive than for Whites because of the smaller sample). Stature trend in American White and Negro populations thus presents minor fluctuations in the nineteenth century followed by a rapid increase in the twentieth century. This total picture of stature trend over a period of 85 consecutive years refutes the hypothesis that stature increases progressively from decade to decade.

The length of the long bones in all four groups showed fluctuations consistent with stature changes in the corresponding time periods. Thus, the feasibility of utilizing such measures in the study of stature trends is demonstrated and even recommended since the effect of the ageing factor and the need for recorded stature of the subject are eliminated. The scope of accessible data for studies of stature trend is enlarged by means of documented skeletal collections.

[Verbatim from original article]

## 1952 PUBLICATIONS

- 26 Munro, Ella H. **PREPARATION OF ANTHROPOMETRIC NOMOGRAPHS.**  
Environmental Protection Branch Report No. 184, U.S. Army  
Quartermaster Climatic Research Laboratory, Lawrence, MA, February,  
1952. 21 pages

**KEY WORDS:** Anthropometric Nomograph, Clothing Design, Equipment Design,  
Key Dimensions

The purpose of this report is to provide simple sources of reference of anthropometric data for use by designers of clothing and other personal equipment.

Seven analyses of Army populations were made in order to present the interrelationships between selected bodily dimensions and two independent dimensions, varying according to the analysis. Each analysis has resulted in a nomograph which is the graphic representation of the interrelationships.

Use of these nomographs will be of aid to the designers and developers of clothing and equipment used by Army personnel, both male and female.

- 27 White, Robert M. **SOME APPLICATIONS OF PHYSICAL ANTHROPOLOGY.**  
Journal of the Washington Academy of Sciences, Vol. 42, No. 3, 65-71,  
March, 1952. Also published as Chapter 10 in: THOMAS W. MCKERN  
(editor) **Readings in Physical Anthropology** (second edition),  
Prentice-Hall, Inc., Englewood Cliffs, NJ, 1972.

**KEY WORDS:** Applied Physical Anthropology, Clothing Design,  
Sizing Systems

Just as some cultural and social anthropologists have adapted their particular fields to contemporary problems, so have some physical anthropologists drawn from their techniques and developed methods by which many problems of everyday living which involve dimensions of the human being may be subjected to scientific analysis and solved in an objective manner. However, the physical anthropologist encounters large numbers of "experts" when approaching any of the numerous problems he or she may solve or help to solve.

Clothing, furniture, and automobiles are all familiar items, but it comes somewhat as a shock to us to find that so little consideration has been given to us, as people, in the design of these articles. One of the greatest handicaps in reaching a mutual understanding with the designer or engineer is the necessary use of statistical knowledge in explaining the problem. Two factors may explain this condition. The first, and fundamentally the most important, is the lack of static and dynamic anthropometric data. Allied with this, although necessarily following it in demand, is the lack of statistical knowledge required to obtain proper application. The second factor, and of equal practical importance, is the universal attitude that the accommodation of the human being is a factor in the general field of competition. Whole industries are willing to standardize sizes of fittings, but the perfectly simple concept of standardization of accommodation for human beings has not yet been accepted.

When the physical anthropologist carefully measures large series of people, develops objective analyses, and proposes results to be introduced into the design of all types of personal equipment or of equipment which requires accommodation of the human being, only part of the work is done. Two parts remain. Designers must be educated in this way of thinking, and then experiments must be set up to convert the anthropometric measurements into terms which will be familiar to the designers. It is the goal of the investigator to provide information for the designer as to the requirements of accommodation. It is the goal of the designer to meet these requirements. Finally, it is the objective of both to obtain the optimum compromise at the minimum cost.

Thus, in the field of applied physical anthropology, the physical anthropologist occupies three successive positions: first, as an anthropometrist in collecting the metric data; second, as a statistician in preparing the "specifications" which describe the requirements; and finally, as an applied physical anthropologist, in analyzing the problem of the designer insofar as it relates to human bodily dimensions, and in providing for the designer in concrete, practical terms the measure of fulfillment of the requirements by the designer. Many times this last role permits the anthropologist to suggest revisions in the original design which will improve its efficiency materially and often reduce its cost.

- 28 Newman, Russell W. **AGE CHANGES IN BODY BUILD.** American Journal of Physical Anthropology, N.S. Vol. 10, No. 1, 75-90, March 1952.

**KEY WORDS:** Age Changes, Body Type, Correlation Coefficients, Somatotype

Before somatotyping can be effectively utilized for personnel selection or like purposes, the question of the permanence of the somatotype must be investigated. The original source of data on this system of body build analysis considered the problem briefly and concluded that the somatotype was permanent in the normal male. This concept has been adopted by followers of the system. Dupertuis says: "one of the premises of the constitutional anthropologist is that the components of an individual's somatotype remain constant, at least after skeletal growth is completed." Everyone will agree that the final test of immutability of the somatotype can only be made by following a large number of subjects for many years. Results of this type of investigation have not yet been published, and it may be many years before sufficient material can be collected. In the interim there is another approach, admittedly not as precise, which can give valuable data. This involves a cross-sectional study of a large number of individuals of varying ages. This paper attempts to explore the question of body build permanence through a study of such age groups.

The problem of stability in body build has been investigated by examining a series of some 40,000 individuals photographed by the U.S. Army and typed at Harvard University. The age groups from 18 through 35 years have been analyzed for: percentage of occurrence for each rating, mean component scores, summation of component scores, product-moment correlation coefficients, and partial correlation coefficients on a year by year basis.

These analyses indicate that definite, although limited, changes are associated with age in this Army series. The 1st and 2nd components increase with age while the 3rd component decreases. The correlation between the 1st and 2nd components and 2nd and 3rd components increase with age but the 2nd and 3rd components retain the same magnitude of association.

Similar values of central tendency and statistical association have been compared for White, Black, and Asian series typed by the Hooton system and White and Asian series typed by the Sheldon system. The values show large differences between investigators that pose problems of comparability in technique.

- 29 White, Robert M. APPLIED PHYSICAL ANTHROPOLOGY. American Journal of Physical Anthropology, N.S. Vol. 10, No. 2, 193-199, June, 1952.

**KEY WORDS:** Applied Physical Anthropology

Scientific research in general consists of two main efforts, not always clear and not necessarily mutually exclusive, but nevertheless usually distinguishable. The first includes investigations which primarily add to our body of knowledge. These are largely the result of our intellectual curiosity. The second comprises studies oriented toward useful or practical applications. These are the result of our desire for improvement of one sort or another. This situation is particularly true in anthropology — the study of humans.

In some scientific disciplines such as mathematics, physics, chemistry, or engineering, careful distinctions are made between pure and applied fields. It does not seem necessary, however, to delimit separate categories of theoretical and practical work in physical anthropology, since most, if not all, types of research in physical anthropology have, or at least should have, ultimate applications of some sort.

Workers in applied physical anthropology need not confine themselves only to immediate problems. Thus the data utilized in the solution of practical problems should also be explored for possible contributions toward theoretical problems. Some of the methods and techniques developed during the course of practical investigations may have wider utilization. In this way, applied physical anthropology can fulfill a useful and profitable function in the field of anthropology as a whole.

Applied physical anthropology, then, is an approach in which attention is focussed upon the solution of practical problems. It is varied in scope and often utilizes modifications or adaptations of conventional techniques. It is a point of view which permits expansion in the general field of anthropology, as well as collaboration with workers in other fields of endeavor.

- 30 Newman, Russell W. MEASUREMENT OF BODY FAT IN STRESS SITUATIONS. Environmental Protection Branch Report No. 193, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, November, 1952. 22 pages

KEY WORDS: Body Fat, Heat Stress, Male Anthropometry, Skinfold Measurements, Survival Rations

This study was initiated to investigate the use of body fat measurements by the skinfold technique in environmental stress situations. Two experiments, one involving a prolonged heat exposure and the other concerned with the consumption of a survival ration, furnished the opportunities to collect the data.

Data on body weight, body fat, caloric intake, and water intake were presented and analyzed for each experiment. Mean values were used for five men in the heat study and for ten men in the ration study. Data on body fat in the heat study indicated that this measure was influenced by the extreme heat (120°F) in which the subjects were placed. The high fat values obtained in the heat were presumably caused by a peripheral vasodilatation which appeared within the initial four hours of exposure. Body weight was influenced by the large quantities of water required in the heat and probably by the small water intake available with the survival ration.

In the absence of heat stress, the skinfold method for estimating body fat gave excellent results; the simplicity of instrumentation and ease of collecting the data make this method ideal for investigating military groups under laboratory or field conditions. The analyses presented in this study indicated that weight loss recorded for the test subjects in both experiments can be closely accounted for in terms of adipose and protein tissue losses.

- 31 Newman, Russell W. THE ASSESSMENT OF MILITARY PERSONNEL BY 1912 HEIGHT-WEIGHT STANDARDS. Environmental Protection Branch Report No. 194, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, November, 1952. 22 pages

KEY WORDS: Age Changes, Civilians, Height-Weight Standards, Male Anthropometry, Medico-Actuarial Data, Secular Trends

This study was made to establish and compare relative weights in three Army series: White male separatees measured in 1946, Black male separatees measured in 1946, and White male inductees measured in 1946 and 1949, with the height-weight table established by the medico-actuarial mortality investigation of 1909-1912, utilized as the standard in this assessment.

The three Army series were uniformly higher than the 1912 medico-actuarial standards in weight. The White and Black separatees demonstrated an unexplained decrease in the average relative weight with age. The White inductees did not show this decrease over the limited available age range. The largest Army group, White male separatees, was compared to two other standards, a European standard which proved unsatisfactory because age was not taken into account, and a study of civilians in 1940 by the Equitable Life Assurance Society. The Equitable Life data showed overall average weights that more nearly approached the Army data but a curious discrepancy in tall-statured men occurred.

The 1912 medico-actuarial data appeared obsolete when a modern military series was judged by these standards. The civilian population of the 1940's, measured at the time of induction into the Army, appeared to lie approximately midway between the military and 1912 series. Some unidentified military factor caused a differential addition of weight with age not found in the civilian data.

- 32 Trotter, Mildred, and Goldine C. Gleser. **ESTIMATION OF STATURE FROM LONG BONES OF AMERICAN WHITES AND NEGROES.** (Contract DA44-109-QM-199, Department of Anatomy, Washington University, St. Louis, MO) American Journal of Physical Anthropology, N.S. Vol. 10, No. 4, 463-514, December, 1952.

**KEY WORDS:** Forensic Anthropology, Human Identification, Long Bones, Racial Variation, Regression Analysis, Skeletal Biology, Stature Estimation, Terry Collection

The estimation of stature from length of long bones of the free limbs is often an important contribution to the identification of unknown human remains. The need for identification was realized, perhaps more keenly than ever before, during the United States Repatriation Program. This program was established by an Act of Congress in 1944. It included the identification (when possible) of unknown war casualties and was assigned to the American Graves Registration Service under the Army Quartermaster Corps. Identification laboratories were established in suitable parts of the world and the aid of physical anthropologists was enlisted.

The American Graves Registration Service has obligations which have stimulated interest in improvement of methods for identification of skeletal remains. Coincidentally, the ideal combination of data for the determination of formulae for estimation of stature from long bone lengths became available. These data are from American White and Black military personnel and comprise measurements of stature during life and measurements of long bones of the free limbs after death. The Terry Anatomical Collection has been introduced into this study in order that formulae from a very different source might be provided; that these two

sets of formulae, after adjustment for differences in age and in measurements of living and cadaver stature, might be tested against each other; and, that formulae for females of both races might be evolved.

Only subjects who were at least 18 years of age when stature was measured have afforded data for the equations of stature estimation. All six long bones were measured for maximum length; in addition, the bicondylar length of the femur and the length between the articulating surfaces of the tibia were taken. The average length of right and left bones of any given pair was utilized in the statistics because of the greater reliability of an average. Furthermore, the differences in length between the bones of the two sides are small and when the bone of only one side is available an adjustment in an equation based on the average is not necessary.

Regression equations for estimation of stature from the length of each long bone and from the lengths of multiple bones were determined for each group of subjects available from the two sources. The single bone equations are almost identical for the two lengths of femur and for the two lengths of tibia; thus only the maximum length of each bone was utilized in the multiple bone equations. Intercorrelations among the lengths of the six long bones are very high, particularly between radius and ulna and between tibia and fibula, so the ulna and fibula were omitted in the multiple bone equations. In both single and multiple equations the bones of the lower limb result in estimations of stature with a smaller standard error than do the bones of the upper limb.

Equations for estimation of long bone lengths (humerus, radius, ulna, tibia, fibula) from femur length are presented for Whites and Blacks of both sexes.

The increase in cadaver stature (measured according to the method of Terry) over that of living stature is estimated to be 2.5 cm. When this correction is made and loss of stature from ageing is taken into account, the equations for estimation of stature of males based on data from the Terry Collection and from the military personnel are shown to be in substantial agreement. It seemed reasonable to assume that equations based on females of the Terry Collection, with corresponding adjustments, are likewise applicable to the American population of White and Black females.

Thus equations (determined from both single and multiple bones) for estimation of living stature of American Whites and Blacks of both sexes are presented. These equations are applicable to maximum lengths of long bones which are dry and without cartilage. The resultant estimates are of maximum living stature and can be reduced by the amount of 0.06 cm (age in years — 30) to cover the effects of ageing. A test of the equations for White males by application to a different sample of American White military personnel gives results well within the expected range of accuracy; comparison of stature estimates according to equations (involving femur and humerus) developed in this study with those of other investigators demonstrates that the present formulae give the most

accurate estimates of stature. Another comparison involving the application of each investigator's equation (based on the femur) to every other sample of like sex demonstrates the advantage of the age factor in the equation and also the need for an adjustment when cadaver stature (as measured by Todd) is utilized as a measurement of living stature.

Blacks of both sexes have significantly longer bones of the free limbs than do the White groups; Blacks also have longer forearm and leg bones relative to the arm and thigh bones than do Whites; and, in general, Blacks have longer bones of the limbs relative to their stature. These comparisons, pointed toward the relationship of the variables, indicate the necessity of independent equations for estimation of stature for each sex of the White and Black races.

### 1953 PUBLICATIONS

- 33 Baker, Paul T. **THE EFFECTS OF A HOT-DRY CLIMATE ON GROSS MORPHOLOGY.** Environmental Protection Branch Report No. 197, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, January, 1953. 25 pages

**KEY WORDS:** Body Fat, Cluster Analysis, Desert, Heat Stress, Hot-Dry Climate, Racial Variation, Skinfold Measurements

This study represents an effort to discover what the effects of a hot-dry climate are on gross body structure, to find the changes, if any, in gross body structure by multiple techniques, and to relate them to the general military problem of the effects of climatological and other physical stresses on the human body.

Of the measures taken on a group of Army personnel on temporary duty at Yuma Test Station, Arizona, only weight and measures derived from weight did not change. The circumferences of mid-arm, shoulder, chest, and waist all showed a loss during the first three to four weeks. Shoulder and arm circumferences lost more than the others. The measures of arm, chest, and waist skinfolds showed a considerable loss as did the derived measure of total body fat. An inspection of the change trends showed that there were three different loss patterns: one, formed by the circumferences; two, formed by the waist and chest skinfolds; and three, formed by the arm skinfold. When the group was broken down into subgroups it was found that Blacks were significantly different than Whites in the measures taken. Division by amount of fat at the first measure also gave two significantly different groups. Loss patterns for these subgroups indicated that each one lost in a different manner than the other. Although all of them lost to some extent, the Blacks showed a smaller loss in most of the measures than the Whites did. The fat men lost more in all the measures than the thin men; however, because the fat men had much more soft tissue to begin with, these losses were not as great relatively as those of the thin men. A breakdown of the group by occupation did not show groups which were different to begin with; neither did any of these subgroups change in a manner which was different from the total group. Cluster analysis indicated that the measures taken represented three groups of measures which were highly related within themselves but not highly related to each other. These three groups were the same ones found by the inspection of the loss trends. From the discreteness of these measurement groups it was hypothesized that the extremities as represented by the arm showed a greater loss in circumferences and fat than the torso.

- 34 Newman, Russell W. CLOTHING SIZE REQUIREMENTS FOR KOREAN MILITARY PERSONNEL. Environmental Protection Branch Report No. 206, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, April 1953. 15 pages

KEY WORDS: Clothing Sizing, Foreign Anthropometry, Korean Military, Tariff Derivation

This study on bodily dimensions of approximately 2,450 Koreans was undertaken to provide clothing design and tariff information applicable to Korean personnel who might be supplied with U.S. Army clothing and equipment. The Korean personnel differed principally from U.S. soldiers in the combination of bodily proportions which would be fitted in clothing. They were characterized by small girths, long bodies, and short extremities. The U.S. clothing is sized to fit popular combinations of length and girth. Korean tariffs for upper and lower body garments were calculated by superimposing U.S. garment sizes on two-dimensional analyses of critical fitting dimensions. It was found that the present sizes of U.S. Army upper body functional clothing gave inadequate coverage for the Korean population, because no X-Long lengths are procured, and because of a deficiency in the number of Long lengths now provided. The U.S. functional lower body garment sizes were also inadequate because of no X-Short lengths. Little or no Korean requirements were found for approximately half of the present U.S. sizes. Tariff requirements for headgear, handgear, and footwear for Korean personnel also were analyzed.

- 35 Newman, Russell W., and Gerald Winston. COMPARISON OF TEN ANTHROPOMETRIC AND TAILORING MEASURES ON THE SAME MEN. Environmental Protection Branch Report No. 210, U.S. Army Quartermaster Climatic Research Laboratory, Lawrence, MA, June 1953. 13 pages

KEY WORDS: Anthropometric Measurements, Measurement Techniques, Tailoring Measurements

This study was undertaken to determine the relationship between two types of measurements, i.e., anthropometric and tailoring. The information could then be applied to the large amount of anthropometric data available on military personnel and would facilitate a translation of anthropometric data into meaningful pattern measurements.

Data on ten bodily measurements — neck, shoulder, chest, waist, and hip (seat) circumferences, sleeve length, scye depth, inside arm length, outseam, and inseam — were presented and analyzed for the relationship between the two types of measurements on 42 men. The relative reliability of the two techniques was assessed and was found to be roughly similar;

the relationships appeared sufficiently consistent to warrant translation from one technique to the other without undue loss of accuracy. Methods for conversion from one type of measurement to the other were presented in several forms if appropriate to individual situations.

- 36 Newman, Russell W. SPECULATION ON THE SIGNIFICANCE OF MUSCLE-BONE RELATIONSHIP IN TERMS OF HUMAN EVOLUTION. American Journal of Physical Anthropology, N.S. Vol. 11, No. 2, 233-235, June, 1953.

KEY WORDS: Human Evolution, Muscle-Bone Relationships, Skeletal Biology

The ultimate aim of human paleontology has been to extrapolate from the fragmentary osseous remains of our ancestors a complete and functional understanding of the animals. Washburn has pointed out the need for extreme care and a sound knowledge of the intimate relationships between bones or portions of bones and the soft tissues which clothe them before this reasonably can be accomplished. This brief communication has as its purpose to point out another area where our information is deficient and to appeal for research designed further to elucidate the general problem of muscle-bone relationships in our conceptual scheme of human evolution.

- 37 Baker, Paul T. COMPARISON OF NEGROID AND WHITE FAT CHANGES UNDER DESERT HEAT STRESS. (Paper presented at the 22nd annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, December, 1952). American Journal of Physical Anthropology, N.S. Vol. 11, No. 2, 260, June, 1953.

KEY WORDS: Body Fat, Desert, Heat Stress, Male Anthropometry, Racial Variation, Skinfold Measurements

In June, 1952, a group of 21 Negroid and 45 White soldiers were measured in Virginia, prior to their departure for a 6-week tour of duty in the Arizona desert. They were subsequently measured at weekly intervals. Measurements used were: weight; mid-arm, shoulder, chest and waist circumferences; subcutaneous fat of the upper arm, chest and waist (by skinfold calipers); and total percentage of fat in the body. In pre-desert measurements, both groups had the same mean stature and weight. The Whites had significantly larger chest and waist circumferences and twice the amount of fat. By the end of the first week in the desert, the Whites had gained in all torso measurements and in total body fat. After this time, there was a steady decrease in torso circumference measurements and in the amount of torso fat. Arm circumference and arm fat decreased continuously, without the initial first-week rise. Negroid measurements did not display the same increase

in fat and circumference during the first week. Instead, a steady loss in fat was recorded for the full test period, while changes in circumference were erratic. Final measurements showed that Negroids lost 25 percent of their original body fat while Whites lost 13 percent. Contrary to expectations, weight losses did not accompany body changes in either racial group. [Abstract]

- 38 Wedgewood, Ralph J., and Russell W. Newman. **MEASUREMENT OF BODY FAT BY AIR DISPLACEMENT.** (Paper presented at the 22nd annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, December, 1952). American Journal of Physical Anthropology, N.S. Vol. 11, No. 2, 260, June, 1953.

**KEY WORDS:** Body Fat, Measurement Techniques, Skinfold Measurements, Specific Gravity

The most practical and accurate method of measuring total body fat is by assessment of specific gravity. All direct specific gravity data are at present obtained through total immersion of the subjects in water. This technique requires cumbersome and non-portable apparatus, a period of subject training before reliable results can be obtained, a careful measurement of the residual air in the lungs, and is inapplicable to the very young or the infirm.

A method which avoids or minimizes the disadvantages of water immersion is that of substituting air displacement for water displacement. A short motion picture showing the apparatus being used on two subjects was presented. The general theory of the measurement of air displacement by electrical means, the methods of calibrating the volumetric cylinder, calculation of body fat on two subjects, and comparison with body fat obtained by skin-fold measurements were shown. [Abstract]

- 39 Newman, Russell W. **MODEL AND SIZE DATA FOR THE DESIGN OF MEN'S CLOTHING.** Environmental Protection Division Report No. 217, U.S. Army Natick Quartermaster Research and Development Laboratory, Lawrence, MA, July, 1953. 18 pages

**KEY WORDS:** Chest Circumference, Clothing Sizing, Key Dimensions, Male Anthropometry, Stature, Waist Circumference

This study presents average data on bodily dimensions of approximately 25,000 U.S. Army soldiers. This series is successively divided into subgroups on the basis of size (chest circumference), model (drop or chest circumference minus waist circumference), and length (stature). Mean values on size groups and models within size groups are presented in tabular and graphic form to facilitate interpretation.

Length groups within the models and sizes are given in tabular form only. The percentage of occurrence of the model groups, i.e., 25 percent of Slender (seven to ten inches of drop), 62 percent Normal (four to seven inches of drop), 10 percent Portly (1½ to four inches of drop), and 1 percent Stout (zero to 1½ inches of drop) indicates that a definite requirement exists for their use in men's service or semidress uniforms. The atypical groups, Slender and Portly, are found with almost equal frequency in all chest size groups. It is recommended that the data presented here be considered in any proposed major revision of the U.S. Army men's service uniform.

- 40 Newman, Russell W. **APPLIED ANTHROPOMETRY**. In: *Anthropology Today, an Encyclopedic Inventory*, prepared under the direction of A.L. Kroeber, Chicago University Press, Chicago, IL, 1953. (pp. 741-759)

**KEY WORDS:** Applied Physical Anthropology

This chapter presents a basic introduction to the principles of Applied Physical Anthropology. To the Webster definition of an "applied science" ("using and adapting abstract principles and theory in connection with concrete problems, especially with a utilitarian aim") is added: "using abstract methods."

An example of a largescale anthropometric survey to establish clothing sizing standards for children is used to present a background. Through this example, a number of important features of applied anthropometry are discussed: 1) "Data which are pertinent to the problem must be available or be gathered;" 2) "The data must be organized and presented in a manner that is not too divergent from existing practices;" 3) "The new concept or system must have demonstrable advantages over the old;" 4) "The results of the applied anthropometry must be skilfully and patiently sold to the manufacturers, retailers, and consumers." Space-requirement studies are discussed as a field for future endeavor.

Four major strengths of anthropometry as a field of endeavor are presented: "First, anthropometry brings a fresh approach to many problems, especially industrial applications . . . . Second, anthropometry has a tradition of experience with and regard for biological variability . . . . Third, there are few biological disciplines with a greater appreciation of the concept of 'population' and of techniques appropriate to the gathering of adequate samples . . . . Fourth, anthropometrists have training in and a regard for precise measuring techniques."

Four major weaknesses of applied anthropometry are also discussed: "First, there is, unfortunately, a preoccupation in the profession with conventional and classical measurements that are often totally unsuited for applied studies . . . . Second, no one can accuse physical anthropology of being a brash and bustling science, and lack of salesmanship, including self-salesmanship, is a disadvantage of this work. Third, there is an unfortunate lack of knowledge as to what the measurements already devised really mean in terms of function . . . . Fourth, there is a distinct shortage of theory to which the worker can turn for advice and guidance."

#### 1954 PUBLICATIONS

- 41 Newman, Russell W. SKINFOLD INTERRELATIONSHIPS IN YOUNG MALES.  
(Paper presented at the 23rd annual meeting, American Association of Physical Anthropologists, Yellow Springs, Ohio, March, 1954).  
American Journal of Physical Anthropology, N.S. Vol. 12, No. 2, 296, June, 1954.

KEY WORDS: Body Fat, Obesity, Racial Variation, Regression Analysis, Skinfold Measurements

Skin-fold thickness used in the calculation of body-fat has not been measured on a single homogeneous sample of sufficient size to allow detailed comparisons of changes with increased obesity. The series reported here, consisting of approximately 1,700 White and 300 Negroid males, permit such comparisons as well as indirect methods of assessing the applicability of calculating body-fat on Negroid males by use of relationships established on Whites.

The racial analyses clearly show a deficiency in subcutaneous fat in Negroids when compared to Whites of a similar age group. The skin-fold sites on the chest and arm appear most distinctive between these groups, but the Negroids are sufficiently similar to the Whites in skin-fold relationships to warrant the use of a common formula for converting skin-folds to percent body-fat.

Analyses of five skin-fold thicknesses on the body indicate that these areas do not show parallel or even linear changes in relation to increasing obesity. This phenomenon raises a question concerning the advisability of using a single linear multiple regression equation in calculating body-fat. [Abstract]

- 42 Daniels, Farrington, Jr., and Paul T. Baker. SUBCUTANEOUS FAT AND BODY COOLING OF MEN IN AIR AT 15°C. Paper presented at a meeting of the American Physiological Society, Madison, WI, September, 1954.

KEY WORDS: Body Cooling, Body Fat, Cold Stress

Summary not available.

## 1955 PUBLICATIONS

- 43 Baker, Paul T. RELATIONSHIP OF DESERT HEAT STRESS TO GROSS MORPHOLOGY. Environmental Protection Division Technical Report EP-7, U.S. Army Quartermaster Research and Development Center, Natick, MA, March, 1955. 27 pages

**KEY WORDS:** Body Composition, Body Fat, Desert, Heat Stress, Lean Body Mass, Regression Analysis, Roentgenographic Cephalometry

A study was made of the effect of a desert climate on gross morphology. A total of 83 men were measured before reporting for duty and at intervals during duty at Yuma Test Station in Arizona, in 1953. Of these, 29 were X-rayed before and after this duty for a more careful analysis of body composition. It was found that there was a fat loss without significant body weight change. Roentgenographic plates of the arm and thigh indicated a fat loss and muscle increase. This finding was the same as was noted for groups performing similar tasks at Yuma, Arizona in 1952.

Also, the relationship of gross morphology to the ability of the individual to resist heat stress was studied in three groups totaling 50 men. Individual resistance to heat stress was measured by walking the men for one hour at a constant pace and then recording their sweat loss, rectal temperature, and pulse rates. It was found that the size of lean body mass was highly correlated to amount of sweat loss, and that percent of fat had a fair order positive correlation to sweat loss and rectal temperature, but the relationship of percent fat to pulse rate was not conclusively established. Although stature was related to sweat loss and pulse rate, it was found to be important only as a variable in body attenuation. The best possible estimation of sweat loss was gained by a multiple correlation of lean body mass, percent fat, and stature. Even though surface area is important in heat regulation, the material indicated it was not a good standard of reference. It was also found that the use of stature and weight as separate entities gave better prediction of sweat loss than a combination of these for an estimate of surface area. Increasing the stress level produced steeper slopes for the regressions of sweat loss to weight and rectal temperature to percent fat. This suggests that gross morphological factors become more important in the individual's ability to resist heat stress as the stress increases.

- 44 Newman, Russell W., and Ella H. Munro. **THE RELATION OF CLIMATE AND BODY SIZE IN U.S. MALES.** American Journal of Physical Anthropology, N.S. Vol. 13, No. 2, 1-17, March, 1955.

**KEY WORDS:** Bergmann's Rule, Body Size, Climate, Cold Stress, Correlation Coefficients, Geographical Variation, Heat Stress, Male Anthropometry

The recent interest in the application of ecological rules to humans has produced impressive evidence of association between elements of body size and temperature. The basic precepts of Bergmann's rule and its application have been fully covered elsewhere and need only to be summarized here. In brief, Bergmann's rule states that subspecies' body sizes increase in colder climates and decrease in warmer climates. This is related by Schreider to the physical principle that the ratio of heat-generating mass (body weight) to heat-eliminating mechanism (body surface area) varies from high ratios in colder climates to lower ratios in warmer temperatures.

An investigation of possible statistical relationships between climatic environment and body size in a sample of youthful, white, American males was carried out. The series, consisting of approximately 15,000 men measured at the time of their induction into the Army, was divided on the basis of state of birth into 48 groups, and average biological and environmental values for each state were correlated. Body weight and stature were measured on the men and surface area was calculated from these values. The average weight divided by the average surface area for each state was also used. Four measures of climatic environment, mean annual temperature, mean July noon "effective" temperature, mean July temperature, and mean January temperature, were analyzed with the measures of body size by the use of correlation coefficients, partial correlation coefficients, and multiple correlation coefficients.

The analysis indicated that there was a correlation which followed Bergmann's rule of larger weights and surface areas, and greater weight per unit of surface area in colder climates. In contrasting the different types of temperature data with body size, it appeared that January temperatures were more closely correlated than the heat stress data or the mean annual temperature. The weight/surface area ratio showed little advantage over a simultaneous analysis of stature and weight by the multiple correlation technique.

Four possible causal factors for the temperature and body size relationships were examined. Regional distribution of groups with common European national extraction, unequal nutritional opportunities caused by economic factors, heat regulation through proportional changes in the heat-generating mass and heat dissipating surface, and the stimulation of appetite and activity in cold were discussed; the last was chosen as most plausible with these data.

The study clearly indicated that association between body size and environmental conditions is not restricted to "primitive" groups. The causes for the association (which can only be hazarded here) may not be the same between groups, but neither can the influence of environment on a person's physical defenses over and above his cultural defenses be discounted. The conclusions of this paper are that Bergmann's rule of body size relationship with environmental conditions is valid in a United States population, and that this relationship is more highly correlated with January than annual or July temperatures. The reasons for this must await further and probably experimental type studies.

- 45 Newman, Russell W. SKINFOLD CHANGES WITH INCREASING OBESITY IN YOUNG AMERICAN MALES. Human Biology, Vol. 27, No. 2, 53-64, May, 1955.

KEY WORDS: Body Fat, Correlation Coefficients, Obesity, Racial Variation, Skinfold Measurements

Two problems involving skinfold measurements on a large series of young American men have been examined in this paper. The results cannot be considered definitive because no independent measure of average body density was available; the conclusions arrived at using the sum of the skinfolds can only be termed indicative.

An analysis of Black and White skinfold relationships through comparison of correlation coefficients between skinfold sites and average skinfold values for increments of obesity showed small and not statistically significant differences between these racial groups. It was concluded that the present data do not show any reason why body fat on Blacks cannot be calculated from the published prediction equation based on White subjects. However, the comparison was limited by the scarcity of obese Blacks; Blacks were observed to have less fat than Whites over the pectoral and triceps regions, and this might become practically significant if very obese Blacks were compared to their White counterparts. This racial difference in the regional distribution of subcutaneous fat is an intriguing problem which should repay further investigation.

A graphic comparison of the various skinfold sites in the combined series of 2,000 men for presumed increments of increasing obesity indicated a change in the proportional representation of the average site values between the lean and fat subjects. The anterior torso areas, chest and abdomen, showed a rise in relative importance with increasing obesity at the expense of the extremity areas; i.e., the arm and knee. This was interpreted to be at least partially the result of physical space limitations in the extremities. It may form a source of error in predicting fat on all men of a comparable age group with a single prediction equation.

This paper has only touched on a few of the interesting possibilities inherent in the skinfold measurements of the 2,000 young men. Its major purpose was to validate, if possible, the calculation of body fat on the 361 Blacks for use in other analyses. It is believed that this has been accomplished, and a new and intriguing field of anthropometric investigation can be developed through the skinfold measurement technique.

- 46 Newman, Russell W. THE RELATION OF CLIMATE AND BODY COMPOSITION IN YOUNG AMERICAN MALES. (Paper presented at the 24th annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, April, 1955). American Journal of Physical Anthropology, N.S. Vol. 13, No. 2, 386, June, 1955.

**KEY WORDS:** Body Composition, Body Fat, Climate, Cold Stress, Correlation Coefficients, Heat Stress, Lean Body Mass

The association of body size and shape with measures of the physical environment has been handicapped because the available measures of size and shape (total body weight and stature) are difficult to accept as indicators of functional homeothermic entities. The use of gross body weight as an indicator of the heat-producing mass of the body ignores the fact that at least two major bodily elements are subsumed by this value, the muscular tissue with accompanying fluids and the fat tissue. Data are presented which divide gross body weight on approximately 2,000 young American White males into two fractions which are more meaningful in this association. Fat free weight is equated with the heat producing mass of the body and body fat calculated from skin-folds is considered as a heat conserving layer surrounding the fat free mass.

Correlation coefficients, partial correlation coefficients, and multiple correlation coefficients between the biological measures (fat free weight and body fat) and climatic data (mean annual, mean January, and mean July temperatures) showed higher values than was found with a much larger series using only weight and stature. Although the interpretation of the statistical relationships between climate and these elements of body composition may be changed by subsequent and more extensive data, it appears that two climatic elements are involved in the problem, body fat being inversely proportional to summer heat and fat free weight inversely proportional to winter cold. [Abstract]

- 47 Baker, Paul T. AN EXPERIMENTAL APPROACH TO THE EFFECT OF CLIMATE ON MAN. (Paper presented at the 24th annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, April, 1955). American Journal of Physical Anthropology, N.S. Vol. 13, No. 2, 387, June, 1955.

KEY WORDS: Body Fat, Climate, Heat Stress, Racial Variation, Stature

Anthropological thought concerning the effect of climate on evolution and race formation has gone through many fads. We still have very little fact. In such a situation, opinion rules supreme. By applying experimental procedures and utilizing physiological, psychological, and anthropological techniques, we are now in a position to do definitive research. Past research done in the desert and in cold chambers indicated that the heat and cold resistance of individuals is closely related to their body composition and configuration. We may also test for racial differences in heat and cold resistance. A study was conducted at Fort Lee, Virginia, to determine whether there is a difference between American Negro and White heat stress resistance. Forty-eight Whites and forty-eight Negroes were matched for body fat, fat free weight, and stature. These men were exposed to equal heat stress by having them hold a walking pace of  $3\frac{1}{2}$  miles per hour for one hour. Sweat loss, rectal temperature, and pulse rate were recorded. During the experimental period weather conditions were cooler than normal for Virginia in August. Rectal temperature was significantly lower for Negroes than Whites. Sweat loss and pulse rate differences were not statistically significant.

The results of this study can be considered as only indicative in that the heat stress was low. Even so, it exemplifies the potential of the approach. The instrumentation and technique are simple enough to apply in the field on native populations. If we had data on the heat and cold resistance of even a few world populations, we would have a solid basis on which to speculate about man's relationship to his climatological environment. [Abstract]

- 48 Jeffrey, Thomas E., and L.L. Thurstone. A FACTORIAL ANALYSIS OF FOOT MEASUREMENTS. Contract Report (Contract DA44-109-QM-1125), The Psychometric Laboratory, University of North Carolina, Chapel Hill, N.C. Environmental Protection Division Technical Report EP-10, U.S. Army Quartermaster Research and Development Center, Natick, MA, July, 1955. 30 pages

KEY WORDS: Factor Analysis, Foot, Fort Knox Foot Survey, Lasts

This report gives the results of a methodological study carried out for the purpose of investigating the nature of some of the critical factors determining the size of feet in Army personnel. Twenty-nine

measures taken from the anthropometric data collected in the Fort Knox Foot Survey were factor analyzed.

Ten factors were extracted accounting for the intercorrelations between these 29 measures with relatively small residuals. The absolute size of the residual correlations after the extraction of the tenth factor was less than or equal to 0.06.

Eight of the ten rotated factors have been interpreted. This interpretation for each factor describes the nature of the underlying parameter responsible for the concomitant variation of the measures with large projections on the factor. Two factors were not interpreted.

The amount of the total variance for each measure accounted for by the ten factors varied from about 100 percent down to 11 percent. This indicates that at least one measurement (100 percent) shares all of its variance with one or more of the remaining 28 measures, and, consequently, could be relatively unimportant in the determination of shoe lasts. On the other hand, measures which share only 10 to 15 percent of their variance with other measures would have to be considered specifically in the proper fitting of shoes.

- 49 Baker, Paul T., Robert F. Byrom, Farrington Daniels, Jr., and Ella H. Munro. **RELATIONSHIP BETWEEN SKINFOLD THICKNESS AND BODY COOLING AT 59°F.** Environmental Protection Division Technical Report EP-14, U.S. Army Quartermaster Research and Development Center, Natick, MA, July 1955. 25 pages

**KEY WORDS:** Body Cooling, Body Fat, Cold Stress, Skinfold Measurements

This study was designed to test the relationship between body fat and body temperatures when men are subjected to a cool environment. Thirty-one men were exposed to an ambient temperature of 59°F (15°C) for two hours. They wore only shorts and were seated for the total period. Rectal and skin temperatures were recorded at 10-minute intervals.

It was found that fat, as measured by skinfold calipers, bore a strong relationship to both rectal and skin temperatures. The greater the percent of fat in the body, the lower the skin temperatures. The correlations were closer between skin temperature and skinfold thickness in specific areas than between skin temperature and the calculated percent of fat in the body. The difference between 1 and 19 percent body fat made 5.9°F difference in the minimum mean weighted skin temperatures.

The correlation between minimum rectal temperature and percent of fat was high: the fattest men maintained near normal rectal temperatures, while the thinnest men had rectal temperatures 1.2°F lower. The examination of stature and fat-free weight correlations indicated that the primary relationship of fat to rectal temperature was modified by variations in body surface area.

The results of the study indicated that fat men, at least while inactive and wearing only shorts, maintain internal body temperatures at a more nearly normal level than thin men, but fat men have lower skin temperatures. This can be interpreted as indicating that subcutaneous fat is acting as an effective insulator.

- 50 Newman, Russell W., and Paul T. Baker. **SPATIAL REQUIREMENTS OF THE NECK-SHOULDER REGION.** Environmental Protection Division Technical Report EP-15, U.S. Army Quartermaster Research and Development Center, Natick, MA, July, 1955. 13 pages

**KEY WORDS:** Acromial Width, Neck, Neck-Shoulder Region, Shoulder

Dimensional analyses were performed on the neck-shoulder region of a sample of U.S. Army soldiers selected on the basis of body build. Measurements of neck height; neck-shoulder angle; acromial width; shoulder width; and a calculation of the square inches involved in two triangles, the shoulder and acromial triangles, are computed from photographs. Statistical tables of the four measured dimensions and two calculated areas are here presented in the form of reference data. Cut-out models of the averages and statistical extremes are provided for graphic visualization. Loss of available space through the addition of a hypothetical quarter-inch layer of clothing is found to approximate one-third of the area in men with extremely small dimensions. Correlations between dimensions of the neck-shoulder region and total body measurements are too low for incorporation into a sizing system for clothing and equipment.

- 51 Daniels, Farrington, Jr., and Paul T. Baker. **SHIVERING IN FAT AND THIN MEN EXPOSED TO AIR TEMPERATURES OF 15°C.** Paper presented at a meeting of the American Physiological Society, Medford, MA, September, 1955.

**KEY WORDS:** Body Fat, Cold Stress, Shivering

Summary not available.

- 52 Newman, Russell W. RECONSTRUCTION OF BODY BUILD FROM THE HUMAN SKELETON. Paper presented at the 8th Summer Seminar in Physical Anthropology, Washington, DC, September, 1955.

KEY WORDS: Body Build, Forensic Anthropology, Human Identification, Skeletal Biology

Summary not available.

- 53 Newman, Russell W. ADAPTATION IN MODERN MAN. Paper presented at a meeting of the American Anthropological Association, Boston, MA, November, 1955.

KEY WORDS: Adaptation

Summary not available.

### 1956 PUBLICATIONS

- 54 Baker, Paul T., and Farrington Daniels, Jr. **RELATIONSHIP BETWEEN SKINFOLD THICKNESS AND BODY COOLING FOR TWO HOURS AT 15°.** Journal of Applied Physiology, Vol. 8, No. 4, 409-416, January 1956.

**KEY WORDS:** Body Cooling, Body Fat, Correlation Coefficients, Regression Analysis, Skinfold Measurements

Body fat, with its low thermal conductivity, has long been considered an important insulator in protecting the body from cooling in cold environments. The present investigation is a study of some of the quantitative aspects of the reactions of the human body to standard cooling conditions, as these reactions relate to body fat content.

By means of correlation coefficients and regression equations between skinfolds and skin and rectal temperatures, it has been demonstrated that when almost nude men are inactive at 59°F (15°C), fat acts as an insulator. Fat men, under the environmental and activity conditions described, maintain higher rectal temperatures but have lower skin temperatures than thin men. The difference between 1 percent and 19 percent body fat produces a difference of 1.2°F (0.7°C) in rectal temperature and 5.9°F (3.3°C) in mean weighted skin temperature during 2 hours of cold exposure.

- 55 White, Robert M. **BODY BUILD AND BODY WEIGHT IN 25-YEAR-OLD ARMY MEN.** Human Biology, Vol. 28, No. 2, 141-145, May 1956. Also published as a chapter in : Josef Brozek (editor) **Body Measurements and Human Nutrition**, Wayne University Press, Detroit, MI, 1956.

**KEY WORDS:** Bi-iliac Diameter, Body Build, Chest Breadth, Civilians, Key Dimensions, Male Anthropometry, Stature, Weight

An analysis of weight and body build was carried out on a series of approximately 3,550 White 25-year-old Army separatees. For each inch of stature, mean weights are presented for small, medium and large groupings of chest breadth and bi-iliac diameter. These results are compared with a table of desirable weights of men age 25 or over, published by the Metropolitan Life Insurance Company of New York.

The material presented in this paper represents only a preliminary investigation of the problem of laterality in body build. However, the weights presented are those for definite categories of body size as determined by the use of chest breadth and bi-iliac diameters. The weights shown in the Metropolitan Life Insurance table, although they approximate fairly closely the Army values, are for categories of body size in which the determination of the size of the frame is not specified or defined in terms of any body diameter.

- 56 Newman, Russell W. SKINFOLD MEASUREMENTS IN YOUNG AMERICAN MALES. Human Biology, Vol. 28, No. 2, 154-164, May, 1956. Also published as a chapter in: Josef Brozek (editor) Body Measurements and Human Nutrition, Wayne University Press, Detroit, MI, 1956.

**KEY WORDS:** Anthropometric Survey, Body Composition, Body Fat, Geographical Variation, Racial Variation, Skinfold Measurements

The growing use of skinfold measurements obtained with constant-pressure calipers has emphasized the need for large-scale surveys of selected populations to develop standards against which future studies can be compared. No single survey will be adequate in this field even within one population, because age, sex, and physical activity differences will require subsampling beyond the capacity of most surveys. This report is not definitive, even in its selected sample of young American adult males, but it should provide data more extensive than presently available. This report will cover two aspects of the skinfold measurements obtained on these men. First, the basic statistics on the measurements will be presented for the use of other workers in the field. Second, geographical and racial groups will be contrasted to show interesting differences between regional subsamples.

Skinfold measurements and derived measures of body composition were obtained on a large series of young, American, White males and a smaller series of young, American, Black Males. The limited age range and possible effects of military selection may restrict the applicability of the data for other purposes but not the internal reliability for comparisons. A racial contrast emphasized the leanness of the young Black male and his distinctive lack of subcutaneous fat over the pectoral and triceps regions. Geographic grouping of the men indicated a regional difference between northerners and southerners in the amount of body fat for both Whites and Blacks. The causes of these differences in body fat are not fully clear, but their relevance to human nutritional and ecological research is obvious.

- 57 White, Robert M. **WEIGHT AND BODY BUILD OF 25-YEAR-OLD ARMY MEN.** (Paper presented at the 25th annual meeting, American Association of Physical Anthropologists, Chicago, IL, April, 1956). American Journal of Physical Anthropology, N.S. Vol. 14, No. 2, 374, June, 1956.

**KEY WORDS:** Anthropometric Survey, Bi-iliac Diameter, Body Build, Chest Breadth, Key Dimensions, Male Anthropometry, Stature, Weight

In an investigation of weight and body build among Army men, an analysis of the relationship between weight and size of frame has been carried out, utilizing data on a series of approximately 3550 25-year-old White Army separatees. Three categories of frame size were established, based upon groupings of men having small, medium, and large chest breadth and bi-iliac diameters. For each inch of stature, mean body weights were derived for men of small, medium, or large frames. [Abstract]

- 58 McKern, Thomas W. **THE SYMPHYSEAL FORMULA: A NEW METHOD FOR DETERMINING AGE FROM PUBIC SYMPHYSES.** (Paper presented at the 25th annual meeting, American Association of Physical Anthropologists, Chicago, IL, April, 1956). American Journal of Physical Anthropology, N.S. Vol. 14, No. 2, 388, June, 1956.

**KEY WORDS:** Age Estimation, Forensic Anthropology, Human Identification, Pubic Symphysis, Skeletal Biology, Todd's Phases

In determining skeletal age from the pubic symphysis, it is customary to use Todd's ten typical age phases. Although these phases are supposed to represent the appearance of the symphysis over periods of time from two to five years in extent and thus ignore the variability within these age periods, surprisingly little effort has been made to improve this system.

Confronted with the problem of analyzing a set of 375 casts of pubic symphyses obtained by Dr. T. Dale Stewart in 1954-1955 from skeletons of American soldiers killed in Korea, and having in mind that the purpose of the analysis was age identification, a new system of formulation had to be devised. The solution of this problem has involved a symphyseal formula similar in many aspects to the formula used in somatotyping. In the symphyseal formula, it seems desirable to use three components divided into five chronological stages. By determining the age distribution of each component stage it is possible to translate any given formula into the most likely age at time of death with its probable error. This paper will be limited to a discussion of the symphyseal formula, emphasizing its advantages over the more static phase system of Todd's. [Abstract]

- 59 Kobrick, John L. **QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES:  
I. SPATIAL DIMENSIONS OF THE 95TH PERCENTILE ARCTIC SOLDIER.**  
Environmental Protection Research Division Technical Report EP-39,  
U.S. Army Quartermaster Research and Development Center, Natick, MA,  
September 1956. 86 pages

**KEY WORDS:** Arctic Wear, Clothed Anthropometry, Handbook, Human Engineering

Section III, Paragraph 8(2) of AR 705-5 states as follows: "The satisfactory development of an item of materiel cannot be achieved without full and timely consideration of the principles of human engineering." For the most part in the past, human engineering considerations have been based upon the characteristics and capabilities of the unrestricted individual operating equipment in an ideal environment. However, these characteristics, capabilities and requirements may be altered completely when the soldier is fully equipped and operating under various combinations of natural and military environmental situations. To insure maximal operational effectiveness, the soldier, his or her clothing and equipment and the machines to be operated must be fully integrated, and human engineering compatibility between the equipped soldier and other military materiel must be achieved. It is the responsibility of the Quartermaster Corps to gather, integrate and provide the data on the abilities, limitations and spatial dimensions of the equipped soldier to the Department of the Army design engineers for use in the development of new items of military materiel.

This report presents human engineering information on the body size of the soldier clothed in the full Arctic uniform. It should be used as a handbook by engineers and designers for establishing space allowances in the design and sizing of soldier-operated equipment. The criterion used is the 95th percentile of Army nude body size, so that the data are concerned with the upper size limit. The information is presented in pictorial form with index scales, so that dimensions can be measured on the pictures and referred to the index scale to establish actual size.

60 Kobrick, John L. QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES:  
II. DIMENSIONS OF THE UPPER LIMIT OF GLOVED HAND SIZE.  
Environmental Protection Research Division Technical Report EP-41,  
U.S. Army Quartermaster Research and Development Center, Natick, MA,  
December 1956. 185 pages

KEY WORDS: Clothed Anthropometry, Gloved Hand Size, Hand, Hand-Operated  
Equipment, Handbook, Handwear, Human Engineering

Protection of the hand from cold or traumatic injury presents a complex problem. Every conceivable method for protecting the hand to some degree interferes with the ability to do things with the hand. Hand dexterity, sensitivity and functional capabilities are all limited by handwear. To the designer of hand-operated equipment, handwear presents the further problem of designing the equipment to accommodate the gloved hand. Knobs, levers, switches, triggers, etc. must be properly sized and spaced to permit satisfactory operation by the individual wearing cold weather handwear.

This report presents human engineering information on the hand size of the soldier wearing various ensembles of Quartermaster protective handwear. It is intended for use as a handbook by engineers for establishing size and space allowances in the design and sizing of hand-operated equipment. The criterion employed is the bare hand size that is equal to or bigger than the hand size of 95 percent of the Army's personnel; i.e., the 95th percentile of the Army hand size distribution. The information is presented in pictorial form with index scales, so that dimensions can be measured on the pictures and referred to the index scale to establish actual size.

## 1957 PUBLICATIONS

- 61 Kobrick, John L. **QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES: III. DIMENSIONS OF THE LOWER LIMIT OF GLOVED HAND SIZE.** Environmental Protection Research Division Technical Report EP-43, U.S. Army Quartermaster Research and Development Center, Natick, MA, February 1957. 185 pages

**KEY WORDS:** Clothed Anthropometry, Gloved Hand Size, Hand, Hand-Operated Equipment, Handbook, Handwear, Human Engineering

To insure effective operation of equipment, sufficient space must be allowed to accommodate the operator wearing the clothing and protective equipment required for the environment. The design engineer could readily achieve this objective by providing for generous space allocation. However, this would in most instances increase the size of the equipment to unacceptable levels. It is only by knowing the maximal and minimal body dimensions of equipped Army personnel that adequate space allocations can be provided on a rational basis. This series of human engineering handbooks, of which this is the third, is designed to provide such guidance information.

This report presents human engineering information on the hand dimensions of the soldier wearing various ensembles of Quartermaster protective handwear. It should prove useful to engineers and designers as a handbook for establishing size and space allowances in the design and sizing of hand-operated equipment. The criterion used is the point below which the smallest five percent of hand sizes fall; therefore, the data are concerned with the lower limit of hand size. The information is presented in pictorial form with index scales, so that the dimensions can be measured on the pictures and referred to the index scale to establish actual size.

- 62 Kobrick, John L. **QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES: IV. DIMENSIONS OF THE LOWER LIMIT OF THE BODY SIZE OF THE ARCTIC SOLDIER.** Environmental Protection Research Division Technical Report EP-51, U.S. Army Quartermaster Research and Development Center, Natick, MA, April 1957. 83 Pages

**KEY WORDS:** Arctic Wear, Body Size, Clothed Anthropometry, Handbook, Human Engineering

The importance of the full and timely consideration of the principles of human engineering for the satisfactory development of items of materiel has become recognized in Army doctrine (AR 705-5). To insure effective

operation of equipment, sufficient space must be allowed to accommodate the operator wearing the clothing and protective equipment required for the environment. It is only through knowledge of the maximal and minimal body dimensions of equipped Army personnel that adequate space allocations can be provided on a rational basis. Because the military operator is provided with Quartermaster clothing and equipment, it is the responsibility of the Quartermaster Corps to provide the dimensions of clothed body size to the Army design engineer for use in the development of compatible soldier-machine systems.

This report presents human engineering information on the body size of the soldier clothed in the full Arctic uniform. It should be used as a handbook by engineers and designers for establishing space allowances in the design and sizing of soldier-operated equipment. The criterion used is the point below which the smallest five percent of body sizes fall; therefore, the data are concerned with the lower limit of body size. The information is presented in pictorial form with index scales, so that dimensions can be measured on the pictures and referred to the index scale to establish actual size.

- 63 McKern, Thomas W., and T. Dale Stewart. **SKELETAL AGE CHANGES IN YOUNG AMERICAN MALES, ANALYZED FROM THE STANDPOINT OF AGE IDENTIFICATION.** Environmental Protection Research Division Technical Report EP-45, U.S. Army Quartermaster Research and Development Center, Natick, MA, May 1957. 179 pages

**KEY WORDS:** Age Estimation, Forensic Anthropology, Human Identification, Skeletal Biology, Skeletal Maturation

This report of skeletal age changes was compiled from the results of extensive identification research on a series of 450 skeletal remains of U.S. war dead repatriated from North Korea under "Operation Glory" during the fall of 1954. The report is divided into eleven chapters: ten outline the progress of age changes in selected skeletal segments, and the eleventh portrays the total pattern of skeletal maturation. To further aid the observer, each chapter includes complete tabular and detailed photographic evidence of the exact nature of skeletal age changes for the particular area concerned. Also, new methods for determining age estimation have been introduced.

The present work can be used as a technical source as well as a practical tool for the age identification of unknown remains.

- 64 Baker, Paul T., and Russell W. Newman. **THE USE OF DRY BONE WEIGHTS FOR IDENTIFICATION.** Environmental Protection Research Division Technical Report EP-55, U.S. Army Quartermaster Research and Development Center, Natick, MA, May 1957. 22 pages

**KEY WORDS:** Commingled Remains, Dry Bone Weight, Forensic Anthropology, Human Identification, Racial Variation, Regression Analysis, Skeletal Biology, Weight

The skeletal remains of 125 individuals were dried and weighed to investigate the feasibility of using bone weight for estimating living weight and for segregating individuals in group burials. Skeletal components formed differing proportions of total skeletal weight in Whites and Blacks; therefore, the racial groups were analyzed separately. Broad categories of living weight can be predicted from total dry skeletal weight or from the weight of dry right femur. The accuracy of prediction is even greater when the procedure is reversed; that is, predicting dry right femur weight from living weight and stature. The separate dry bone weights were found to be closely correlated to each other in most cases; in conjunction with length measurements they may be used for a highly reliable method of segregating commingled remains into individuals. The regression equations and a practical example for segregating individuals are provided in the appendices.

- 65 Baker, Paul T. **SPATIAL DYNAMICS OF THE NECK-SHOULDER REGION.** Environmental Protection Research Division Technical Report EP-56, U.S. Army Quartermaster Research and Development Center, Natick, MA, May 1957. 17 pages

**KEY WORDS:** Movement, Neck, Neck-Shoulder Region, Shoulder

A study was made of the dimensional changes caused in the shoulder-neck area by movement. Twenty-one men were photographed, each in seven poses, and measurements were made on the enlarged photographs. The seven poses were chosen to show the effects on the measurements of moving the arm, head, and shoulder. The measurements included total shoulder length, effective shoulder length, total shoulder area, and effective shoulder area. Tables summarizing these measurements in each pose are given in the text, and their utility in clothing and equipment design is discussed. It was concluded that the addition of any equipment or clothing in this region restricts movement, and that the design of any new item to be used or worn in this area should take into consideration several factors: the items already prescribed for the area; the movements of the region required to fulfill the prescribed military tasks; and the measurement of this area when the soldier is performing these tasks.

- 66 McKern, Thomas W. ESTIMATION OF SKELETAL AGE FROM COMBINED MATURATIONAL ACTIVITY. American Journal of Physical Anthropology, N.S. Vol. 15, No. 3, 399-408, September 1957.

**KEY WORDS:** Age Estimation, Forensic Anthropology, Human Identification, Pubic Symphysis, Skeletal Biology, Skeletal Maturation

The calculation of age at death from the observed status of skeletonized remains is one of the principal identification methods provided by the physical anthropologist. While the application of this technique has long proved invaluable to both military and civilian agencies involved in human identification work, there exist inherent limitations which arise partially from the subjective nature of the method as well as the lack of well documented skeletal series with adequate age coverage. Within the framework of subjective method, it is generally believed that, because of the high variability of individual maturative events, more precise age estimations may be derived by pooling all available criteria and giving final age assessments as crude averages. Thus, as research on the maturative activity of new areas is completed, they are added to the list of aging criteria on the assumption that each new addition tends to further minimize excessive individual weighting. However, the validity for combining many individual observations has never been objectively tested for methods of age identification. Based on an analysis of data collected on a thoroughly documented sample of American war dead, it is the purpose of this paper to test the application of the concept of combined maturation as it relates to estimations of skeletal age.

The degree of relationship between combined maturational score and age has been tested for five groups of skeletal growth areas. The data indicate that an age estimation derived from the combined maturational activity of a small group of critical growth areas is as reliable as an estimation based on the total number of maturative events. To the identification specialist, this information means that instead of the usual practice of emphasizing complete skeletal coverage, dependable age estimations can be obtained from the combined maturational activity of a small number of critical areas. Also, because of the tested reliability of the symphyseal surface of the pubic bone, the use of other aging criteria is necessary only where the pubic symphysis is damaged or missing (at least for age groups over 17 years).

- 67 White, Robert M. **APPLIED ANTHROPOMETRY OF THE FOOT.** (Paper presented at the 26th annual meeting, American Association of Physical Anthropologists, Ann Arbor, MI, April 1957). *American Journal of Physical Anthropology*, N.S. Vol. 15, No. 3, 445, September 1957.

**KEY WORDS:** Applied Physical Anthropology, Foot, Footwear

One aspect of military research and development in the Quartermaster Corps is concerned with the anthropometry of the foot and the development of military footwear. In recent years, this effort has followed the pattern of data collection, analysis and synthesis, application and testing. In this paper, available sources of anthropometric data on the foot are reviewed and several types of analyses are discussed. Several examples of the applications of anthropometric measurement and analysis are presented. [Abstract]

- 68 Newman, Russell W. **XERORADIOGRAPHY — A NEW TECHNIQUE FOR LIVING ANATOMY.** (Paper Presented at the 26th annual meeting, American Association of Physical Anthropologists, Ann Arbor, MI, April 1957). *American Journal of Physical Anthropology*, N.S. Vol. 15, No.3, 448, September 1957.

**KEY WORDS:** Forensic Anthropology, Human Identification, Skeletal Biology, Xeroradiography

Operational procedures of a new radiographic medium, Xeroradiography, are illustrated and explained. This technique which uses photosensitized selenium-coated plates instead of conventional X-ray film and utilizes a dry developing method emphasizes small, sharp discontinuities in bone with remarkable presentation of soft parts detail. Its speed of development, absence of sensitivity to background radiation, and wide density latitude make it appear ideal for use in a military war dead identification program as a method of locating and analyzing healed bone fractures. [Abstract]

- 69 Baker, Paul T., and Russell W. Newman. **THE USE OF BONE WEIGHT FOR HUMAN IDENTIFICATION.** *American Journal of Physical Anthropology*, N.S. Vol. 15, No. 4, 601-618, December 1957.

**KEY WORDS:** Commingled Remains, Dry Bone Weight, Forensic Anthropology, Human Identification, Racial Variation, Regression Analysis, Skeletal Biology, Weight

Within the past few years, physical anthropologists have become increasingly involved in the problems of human identification. Techniques have been applied to individuals which were originally devised for the

description of groups, and while these are the best available, they do not provide the desired certainty for the identification of an individual. Recent work on identification criteria has concentrated on improving the existing methods. There is obviously a need not only for the improvement of older methods, but also for the establishment of new criteria. With this in mind, research was undertaken by Army Graves Registration Service Headquarters, Kokura, Japan, on the war dead remains that were being repatriated during "Operation Glory".

The skeletal remains of 125 individuals were dried and weighed to investigate the utility of bone weight for identification and for segregating individuals in group burials. Skeletal components formed differing proportions of total skeletal weight in Whites and Blacks; therefore, the racial groups were analyzed separately.

It was found that broad categories of living weight can be predicted from total dry skeletal weight or from the dry right femur weight. However, the reliability of associating bone weights with living measurements can be increased by reversing the procedure; that is, predicting dry right femur weight from living weight and stature. The separate dry weights of the bones were found to be closely correlated to each other in most cases; in conjunction with length measurements they may be used for a highly reliable method of segregating commingled long bones into individuals. The regression equations and a practical example for segregating individuals are provided in the appendices.

## 1958 PUBLICATIONS

- 70 Baker, Paul T., Edward E. Hunt, Jr., and Tulika Sen. **THE GROWTH AND INTERRELATIONS OF SKINFOLDS AND BRACHIAL TISSUES IN MAN.** American Journal of Physical Anthropology, N.S. Vol. 16, No. 1, 39-58, March 1958.

**KEY WORDS:** Adipose Tissue, Body Composition, Body Fat, Brachial Tissue, Gender Variation, Radiographic Analysis, Skeletal Growth, Skinfold Measurements.

A set of latero-medial radiographs of the brachium were taken in a series of children and adults of both sexes. On the children, skinfolds were also measured. The radiographic tissue shadows were transformed into areas of cross section of the brachium so that the growth of the marrow cavity, compact bone of the humerus, musculature and subcutaneous adipose layer could be measured separately. These areas were chosen to assess "parsimoniously" the growth of these tissues.

Like previous investigators, we found that skinfolds efficiently predict the radiographic thickness of skin plus subcutaneous tissue. Specific equations, however, are probably needed for specific sites, age ranges, and perhaps, in some cases, for males and females.

As earlier workers have noted, females tend to have thicker skinfolds than males at all ages past early infancy. The relative concentration of this tissue in the trunk in girls is exaggerated after pubescence.

In the brachium, boys show a decline in the percentage of adipose tissue from childhood to maturity. Girls show a far smaller decline until pubescence, and then a small increase. At all ages, the average female brachium is more adipose than that of the male, and in the young adult the sex difference is more than two to one. The age-stability of composition of the female brachium apparently corresponds to an equal stability of body composition in the female which seems to begin no later than 10 years of age.

In both sexes, the lean brachium has a similar size and composition until about 10 years of age. In older boys, the size of the brachial muscles nearly doubles while girls show only a slight increase in muscle mass.

At 6 years of age, the female brachium contains more compact bone than that of the male. At eight years of age and older, the humeral area is greater in males. In adolescence, the periosteum is far more active in boys than in girls, and this may produce the rugged surface details and massiveness of the mature male skeleton.

In boys, endosteal resorption keeps pace with periosteal apposition through adolescence. In girls, however, the marrow cavity reaches its adult size by 12 years of age. Some connection may exist between this cessation of growth and the great increase of estrogen secretion at this age.

In the adult male series, the correlations among the cross-sectional areas of marrow, compact bone, muscle and subcutaneous adipose tissue are all low, and most are not significantly greater than zero. This independence of size of brachial tissues justifies the separate measurement of each constituent in researches on mechanisms of growth. This finding also discredits the anatomical basis of the mesomorphic scale of constitutional assessment, which is supposedly based on the covariation of bone width, cortical thickness, and muscle size. The lack of significant correlation between bone and muscle size emphasizes that one should not exaggerate the interdependence of these tissues in their amounts and patterns of growth.

- 71 Trotter, Mildred, and Goldine C. Gleser. A RE-EVALUATION OF ESTIMATION OF STATURE BASED ON MEASUREMENTS OF STATURE TAKEN DURING LIFE AND OF LONG BONES AFTER DEATH. (Contract DA19-129-QM-562, Department of Anatomy, Washington University, St. Louis, MO). American Journal of Physical Anthropology, N.S. Vol. 16, No. 1, 79-123, March 1958.

KEY WORDS: Forensic Anthropology, Human Identification, Long Bones, Racial Variation, Regression Analysis, Secular Trends, Skeletal Biology, Stature, Stature Estimation

This study of estimation of stature from length of long limb bones is the second to be based on measurements of stature during life and of bones after skeletonization. The first study was based on American military males who were casualties of World War II, and the present study is based on casualties of the Korean War. The present data include much larger series of both Whites and Blacks than did the first study and also a small series of Asians, Mexicans, and Puerto Ricans.

Regression equations for estimation of stature of American males of each of the five groups have been determined from these data. The relationships of stature to length of long limb bones differ sufficiently among the three major races (White, Black, Asian) to require different regression equations from which to derive the most precise estimates of stature for individuals belonging to each group. The Puerto Rican group, although of shorter stature than the American Black group, presents in this series of data approximately the same relationship of stature to length of long bones as does the Black group, and thus the equations for

estimation of stature derived from the data of the Black series are applicable to Puerto Ricans. The proportions found in the small sample of Mexicans differ sufficiently from those of any of the other four groups to indicate that separate equations for estimation of stature derived from Mexican data are necessary to provide the most precise estimates for Mexicans.

The standard errors of estimates of stature from lengths of long bones are larger in the present series of White males than in the series of the previous study. The primary reason for this difference is attributed to the evidence that stature and its relationship to long bone lengths are in a state of flux, since some individuals over 21 years of age with given bone lengths are taller today than were individuals six to ten years ago with the same bone lengths.

American White males of the present generation are continuing to grow until at least 21, and possibly 23, years of age before maximum stature is attained. This finding is in contrast to that obtained from extensive World War II data in which there was no significant increase in stature after 18 years of age. The longer period of growth in stature of the present military series than of the World War II series and the nature of the growth curve for this terminal period were substantiated in two sets of longitudinal growth data, wholly unrelated to the military series. It is probable that growth in stature is occurring after 18 years of age in all groups in the U.S.A. at the present time. By using the theoretical growth curve with constants computed from the American White military data, averages of the amount of increase in stature for each one-half year interval are provided from age 17 to 21 years. These averages should be applied, when appropriate, to observed or "presumed stature." The application is indicated in identification problems which involve a time lapse between the measuring of stature and the completion of growth in stature.

On the basis of the difference found in stature-long bone length relationships between the World War II and Korean War series, it is indicated that equations for estimation of stature should be derived anew at opportune intervals.

- 72 Baker, Paul T. **AMERICAN NEGRO-WHITE DIFFERENCES IN HEAT TOLERANCE.** Environmental Protection Research Division Technical Report EP-75, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, June, 1958. 23 pages

**KEY WORDS:** Body Fat, Heat Stress, Racial Variation, Stature, Weight

The physiological responses of American White and Black soldiers were studied under hot-wet and hot-dry conditions. Under hot-wet conditions, 40 pairs of men matched for body fat, weight, and stature were walked around a course at 3½ mph for one hour. Under hot-dry conditions, eight

of the men, also matched for body fat, weight, and stature, were studied under eight different conditions which included combinations of clothing, sun, shade, walking, and sitting.

The results of this series of experiments indicated:

- 1) Under hot-wet conditions with both Blacks and Whites clothed and walking, the Blacks had a higher physiological tolerance.
- 2) Under hot-dry conditions with both groups clothed, walking or sitting they had about equal tolerance.
- 3) Under hot-dry conditions with both groups nude and exposed to the sun, sun-tanned Whites had the higher tolerance.

These results further suggested that the differences found were not a function of transient environmental effects and are mostly genetic in origin.

- 73     Baker, Paul T. A THEORETICAL MODEL FOR DESERT HEAT TOLERANCE.  
Environmental Protection Research Division Technical Report  
EP-96, U.S. Army Quartermaster Research and Engineering Center,  
Natick, MA, July 1958. 32 pages.

**KEY WORDS:** Adaptation, Body Fat, Desert, Heat Stress

Humankind probably evolved in a subtropical climate; consequently humans are best adapted to those conditions. However, with a minimum of cultural aids humans later spread into most of the world's climatic zones. This spread implies that there was probably secondary adaptation to cold and hot climatic conditions.

Experimental and actuarial data indicate that there is a high degree of individual variance in ability to tolerate hot desert conditions. The same data also show that a significant percentage of this variance is correlated with morphological characteristics. A model was constructed from these relationships. The model of "ideal" morphology for tolerance of desert heat was found to be linear, low in subcutaneous body fat, acclimatized, and of dark skin color.

These characteristics in the adult are all the product of genetic inheritance working through the environment and, with the exception of acclimatization, training can do very little to modify them.

A survey of world populations indicated a trend for desert populations to conform more closely to the model than other populations. This trend may be considered further confirmation of the validity of the model and it was concluded that, first, desert populations show genetic adaptations to the climate and second, the model characteristics may be used to select groups of individuals who are above average in desert heat tolerance.

- 74 McKern, Thomas W. THE USE OF SHORT WAVE ULTRA-VIOLET RAYS FOR THE SEGREGATION OF COMMINGLED SKELETAL REMAINS. Environmental Protection Research Division Technical Report EP-98, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, August 1958. 11 pages

KEY WORDS: Commingled Remains, Forensic Anthropology, Human Identification, Skeletal Biology, Ultra-Violet Radiation

The identification specialist is often confronted with human skeletal remains that comprise two or more individuals. By using a combination of standard techniques, such as articulation, bi-lateral and serial symmetry, osteometry, and reconstruction, one may achieve segregation after long and careful analysis. As a part of the Quartermaster Corps research program to improve present identification techniques, as well as to devise new methodology for the identification of American war dead, the present study describes and evaluates a fast and simple test for sorting individual remains from mixed burials.

When bone surfaces are exposed to short wave ultra-violet irradiation, most of them reflect a variety of colors. The wide range of color emission, as well as the fixed relationship of these colors to the substances that emit them, is justification for attempting to apply these qualities to the segregation of commingled skeletal remains.

After demonstrations of the results of ultra-violet exposure on a large sample of skeletal material, it is suggested that short wave ultra-violet lamps can be used in certain instances for the accurate sorting of commingled remains.

- 75 Baker, Paul T. RACIAL DIFFERENCES IN HEAT TOLERANCE. American Journal of Physical Anthropology, N.S. Vol. 16, No. 3, 287-305, September 1958.

KEY WORDS: Adaptation, Body Fat, Heat Stress, Racial Variation, Stature, Weight

The science of genetics has emphasized the importance of natural selection in the formation of taxonomic races. This in turn indicates the desirability of a re-evaluation of human races in terms of the possible sources of selective forces. Such a re-evaluation may be based on ecological inferences from the distribution of modern races; or specific hypothesis may be tested by experimental means.

It is the purpose of this study, using the experimental approach, to compare the heat stress resistance (heat tolerance) of Blacks and Whites. The development of this type of knowledge will eventually permit us to define some of the role of climate in the selection of certain morphological characteristics.

The physiological responses of American White and Black soldiers were studied under hot-wet and hot-dry conditions. Under hot-wet conditions, 40 pairs of men matched for body fat, weight, and stature were walked around a course at 3½ miles per hour for one hour. Under hot-dry conditions, eight pairs of men, also matched for body fat, weight and stature, were studied under eight different conditions which included combinations of clothing, sun, shade, walking, and sitting.

The results of this series of experiments indicated that:

1. Under hot-wet conditions with both Blacks and Whites clothed and walking, the Blacks had a higher physiological tolerance.
2. Under hot-dry conditions with both groups clothed, walking or sitting they had about equal tolerance.
3. Under hot-dry conditions with both groups nude and exposed to the sun, sun-tanned Whites had the higher tolerance.

These results further suggested that the differences found were not a function of transient environmental effects and may be mostly genetic in origin. The results are discussed in relation to racial taxonomy systems and the distribution of human morphological attributes.

- 76 Jones, Charles E., John L. Kobrick, and Henry F. Gaydos.  
**ANTHROPOMETRIC AND BIOMECHANICAL CHARACTERISTICS OF THE HAND.**  
Environmental Protection Research Division Technical Report EP-100,  
U.S. Army Quartermaster Research and Engineering Center, Natick, MA,  
September, 1958. 20 pages

**KEY WORDS:** Biomechanics, Hand, Handwear

Optimal design of manually-operated equipment and of handwear which provides environmental protection must take into consideration the size, shape, and relationships between the various parts of the human hand, and the types and amount of movements and forces that the hand and parts of the hand can accomplish. Such data on the structural and functional characteristics of the hand are widely scattered through the scientific literature, frequently in a form quite unusable by the design engineer. The need to collate, synthesize, and present such pertinent data in a form readily available for use by design engineers was recognized by the scientists familiar with the sources of the information and the present report was prepared to fill this need.

Descriptive data are presented on the structural and functional characteristics of the human hand which are of interest to engineers concerned with the design of handwear and manually-operated equipment. The first section deals with the anthropometric dimensions of the hand, and shows the percentile distributions of component hand sizes in several military population samples. The second section reviews data on the biomechanics of the hand in terms of direction, range, and forces involved in typical functional movements.

- 77 Newman, Russell W. **SMALL UNIT CLOTHING TARIFFS.** Paper presented at the 4th Annual Army Human Factors Engineering Conference, Baltimore, MD, September, 1958.

**KEY WORDS:** Tariff Derivation

Summary not available.

### 1959 PUBLICATIONS

- 78 Hooton, Earnest A. **BODY BUILD IN A SAMPLE OF THE UNITED STATES ARMY.** Contract Reports (Contracts W44-109-QM-1078 and 2014), Department of Anthropology, Harvard University, Cambridge, MA. Environmental Protection Research Division Technical Report EP-102, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, February 1959. 358 pages

**KEY WORDS:** Anthropometric Measurements, Body Type, Occupational Activities, Stature, Weight

The two reports which comprise this volume represent a unique experiment in the analysis of body build and the final scientific accomplishment of the author, Earnest A. Hooton, Professor of Anthropology at Harvard University. His untimely death in 1954 left this work in the form of two contractor's reports, each reproduced in only a handful of copies and those scattered into some very obscure governmental and academic corners. On the other hand, there have been an amazing number of references to these reports and citations from them in anthropological literature by authors who could not have had even continuous access to a copy. This Command continues to receive requests for these reports -- requests that could not be filled from the single file copy of each on hand. In the year or two preceding his death, Professor Hooton indicated his awareness that the limited number of copies restricted the full utilization of this work and spoke of reorganizing the material for publication as a book -- a process of popularizing scientific work at which he was extremely successful.

We have not attempted to rewrite Dr. Hooton's reports; the only factual changes have been to correct typographical errors (principally statistical) which could be identified by cross-checking between the tables and the text. In any event, the real worth of these reports is in the statistical tabulations of data on a sample which may never be equalled for size and coverage. It was with the feeling that such a fund of scientific information cannot be allowed to lapse into obscurity that this reprinting of Dr. Hooton's reports was undertaken.

Part I covers: (1) the general distribution of body types classified into 18 groups, as determined from the assessments of individuals by morphological studies of photographs and the use of the stature divided by the cube root of weight index; (2) the military utility of each of the several groups, whether for combat or service, as indicated by the extent to which various body types tended to be concentrated in distinct Army units and specialties; (3) the correlations of the body build groups with all sociological and other data compiled in the survey, such as age, months of service, birthplace, etc.

Part II deals with the more important measurements gathered on individual soldiers during the course of the survey, as such measurements apply to various body types, previously determined from the photographs.

- 79 Kobrick, John L. **QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES: VI. SIZE LIMITS OF THE HEAD AND NECK AREA OF THE SOLDIER WEARING QUARTERMASTER HEADGEAR.** Environmental Protection Research Division Technical Report EP-107, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, March 1959. 87 pages

**KEY WORDS:** Clothed Anthropometry, Handbook, Head, Headgear, Human Engineering, Neck

The importance of the full and timely consideration of the principles of human engineering for the satisfactory development of items of materiel has become recognized in Army doctrine (AR 705-5). To insure effective operation of equipment, sufficient space must be allowed to accommodate the operator wearing the clothing and protective equipment required for the environment. It is only through knowledge of the maximal and minimal body dimensions of equipped Army personnel that adequate space allocations can be provided on a rational basis. Because the military operator is provided with Quartermaster clothing and equipment, it is the responsibility of the Quartermaster Corps to provide the dimensions of clothed body size to the Army design engineer for use in the development of compatible soldier-machine systems.

This report presents human engineering information on the size range of the head and neck area of the soldier wearing Quartermaster headgear. It should be used as a handbook by engineers and designers for establishing space allowances in the design and sizing of soldier-operated equipment. The criteria used are the points beyond which the largest 5 percent and the smallest five cent of head sizes fall; therefore, the data are concerned with the middle 90 percent of the range of head sizes for the Army population. The information is presented in pictorial form with index scales, so that dimensions can be measured on the pictures and referred to the index scales to establish actual size.

80 McKern, Thomas W., and Ella H. Munro. A STATISTICAL TECHNIQUE FOR CLASSIFYING SKELETAL REMAINS. American Antiquity, Vol. 24, No. 4, 375-382, April 1959.

KEY WORDS: California, Commingled Remains, Cranium, Discriminant Analysis, Forensic Anthropology, Human Identification, Skeletal Biology

Due to the inherent difficulties of assigning individual skeletal material to its parent population, we have demonstrated a statistical procedure, the linear discriminant function, that results in an unusually small percentage of misclassification for two California samples. If metric data for the auricular height, maximum bizygomatic diameter, maximum femoral length, and subtrochanteric diameter (a-p) are available for unknown remains, the probability for accurate affiliation is approximately 92.6 percent. A somewhat smaller probability of classification (91.4 percent) may be reached by using three cranial measurements (glabella-occipital length, auricular height, and maximum bizygomatic diameter).

Since the type and range of morphological differences between the two California groups do not represent those for all populations, the present equations are not applicable outside of the tested area. To solve similar problems of association in other localities, discriminatory equations should be calculated and critical index values established for samples of probable parent groups. Moreover, combinations of measurements suitable for one area are not necessarily so for others. Thus, we recommend that a variety of combinations be tested to demonstrate the highest probability of classification. Once established, tables of critical index values may be used as standard tools for skeletal classification.

[Verbatim from original article]

## 1960 PUBLICATIONS

- 81 Sassouni, Viken. **IDENTIFICATION OF WAR DEAD BY MEANS OF ROENTGENOGRAPHIC CEPHALOMETRY.** Contract Report (Contract DA19-129-QM-739), Graduate School of Medicine, University of Pennsylvania, Philadelphia, PA. Environmental Protection Research Division Technical Report EP-125, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, February 1960. 71 pages

**KEY WORDS:** Face, Forensic Anthropology, Head, Human Identification, Roentgenographic Cephalometry

It is axiomatic in the field of war-dead identification that successful identification is largely a function of how much we know about a given individual. Unfortunately, we don't know too much about our soldiers before death that materially assists in identification after death. The research here reported rests on just one assumption; that we had an additional piece of biological data -- a postero-anterior X-ray of the head and face -- before death, and sought to establish what assistance this would be in identifying remains. The answer clearly was that it would be of great assistance, since a simple combination of head and face measurements taken from such X-rays is highly diagnostic. This research demonstrated a truth that is often forgotten: every soldier is a unique individual, and the implications and importance of individuality are worthy of continued emphasis.

This report describes a new method of identification of war dead by means of roentgenographic cephalometry. Head X-rays were taken twice on 500 adult males. The most characteristic measurements were selected from the films. By a system of coding, tests of identification were performed with a high-speed computing machine. Measurements, selection, and identification took two minutes per person; 100 percent accuracy was obtained during these tests.

Suggestions have been made to improve the method and possibly to extend its use for the civilian population.

Publication of this research study should not be interpreted as an indication that the Army plans to utilize this means of identification in the foreseeable future.

- 82 Kobrick, John L., and Brian Crist. **QUARTERMASTER HUMAN ENGINEERING HANDBOOK SERIES: VII. THE SIZE AND SHAPE OF THE AVAILABLE VISUAL FIELD DURING THE WEARING OF ARMY HEADGEAR.** Environmental Protection Research Division Technical Report EP-133, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, May 1960. 25 pages

**KEY WORDS:** Clothed Anthropometry, Handbook, Headgear, Visual Field

The reduction of incompatibilities in military equipment systems requires that one know what limitations are placed on the operator by use of the equipment. In the case of headgear, the wearer's field of vision is almost sure to be reduced to some degree by the very fact that something with an overhang is placed on the head. By the time that essential physical protection has been built into the item, the field of vision may be restricted considerably. Knowledge of the extent of such limitations is essential to engineers and equipment designers engaged in the development of headgear and related equipment.

This report furnishes information in tabular form on the size and shape of available visual fields during the wearing of 12 Army headgear ensembles. Schematic diagrams are also provided to aid in visualizing size and shape of the visual fields.

- 83 McKern, Thomas W. **THE FLUORESCENCE OF HUMAN BONE AS VIEWED UNDER SHORT WAVE ULTRA-VIOLET RAYS.** (Paper presented at the 27th annual meeting, American Association of Physical Anthropologists, Cambridge, MA, April 1958). American Journal of Physical Anthropology, N.S. Vol. 18, No. 4, 337, December 1960.

**KEY WORDS:** Commingled Remains, Forensic Anthropology, Human Identification, Skeletal Biology, Ultra-Violet Radiation

When most bone surfaces are exposed to short wave ultra-violet radiation, they react by reflecting a variety of colors. The wide range of color emissions, as well as the stable characteristics of these colors for the substances that emit them, is basis enough for attempting to apply these qualities to the segregation of commingled skeletal remains. After demonstrating the results of U-V exposure on a large sample of skeletal material, it is suggested that short wave ultra-violet lamps can be used in some instances for the accurate sorting of commingled remains.

[Abstract]

- 84 Sassouri, Viken. A METHOD OF IDENTIFICATION OF WAR DEAD BY MEANS OF ROENTGENOGRAPHIC CEPHALOMETRY. (Paper presented at the 27th annual meeting, American Association of Physical Anthropologists, Cambridge, MA, April 1958). American Journal of Physical Anthropology, N.S. Vol. 18, No. 4, 338, December 1960.

**KEY WORDS:** Correlation Coefficients, Forensic Anthropology, Head, Human Identification, Roentgenographic Cephalometry

The problem posed by the Quartermaster Research and Development Command was: "What are the five measurements of the head and face (as seen in the frontal and lateral X-ray films) which are the most variable, the least correlated, and the most reliable, that can be used for identification purposes? The mandible should not be included in more than one measurement. The test should be carried out on 500 adult males above eighteen years of age." This study was conducted at the Philadelphia Center for Research in Child Growth.

Four hundred and ninety-eight males were X-rayed twice with the E. J. Badger-Bolton roentgenographic cephalometer; the first set represents the ante-mortem films (AM) and the second set the postmortem films (PM). Two hundred and forty-eight were X-rayed in Philadelphia; 70 at the Bolton Fund, Western Reserve University; 120 at the University of Illinois; and 110 at the National Institute of Health. They represent a cross-section of young adult American males.

For various reasons, but basically in order to obtain the greatest variability for the minimum error, and, at the same time, to avoid tracing, linear dimensions were selected as the method of measurement. Twenty-four measurements were selected on the frontal film. Large error, low variations, and duplications eliminated 16 of them. The remaining eight measurements are: frontal sinus breadth, facial height, bigonial, cranial height (mastoid-apex), incision height, bizygomatic, bimaxillary, and maximum cranial breadths. Twenty-four measurements were selected on the lateral film. The remaining eight measurements are: height of the cranium 8 cm posterior, 4 cm posterior, just above, and 4 cm anterior to center of the sella turcica; facial height (Na-Me); cranial length along Nasion-Sella, 4 cm above, and eight cm above.

A correlation table was computed among the 16 selected measurements (eight frontals, eight laterals). From these 16, the five best measurements in terms of high variability, low error, and low correlation were selected by individual simultaneous computations. These five measurements are: length of cranium 4 cm above Na-S, sinus breadth, total facial height, bigonial and bizygomatic breadths. They are the most characteristic of the individuality of an adult male.

Since four of the five selected measurements are from the frontal film, and in order to realize a 50 percent economy, an attempt was made to use only the frontal film for purposes of identification. A test was made to identify 100 PM frontal films from 498 AM films. A special routine was written to permit location and neutralization of accidental errors. The test was conducted on a Univac machine. It took ten seconds for the Univac machine to locate the correct film out of 498 possibilities. Direct identification was made on 97 percent; 3 percent could be identified by direct comparison with the remaining films. It can be stated, therefore, that the test of identification was 100 percent successful.

Suggestions were made which, if adopted, may lead to: increasing the standardization of the entire process; decreasing the errors; creating a mobile roentgenographic unit; initiating a longitudinal study of the growth of head and face in adults.

In conclusion, identification can be realized with 100 percent accuracy. At the same time, the roentgenographic films gathered will constitute for medical and dental health units an invaluable source of information on one of the most vital areas of the human body. [Abstract]

- 85 White, Robert M. **STATURE INCREASE IN THE U.S. MILITARY POPULATION.** (Paper presented at the 28th annual meeting, American Association of Physical Anthropologists, Madison, WI, May 1959). American Journal of Physical Anthropology, N.S. Vol. 18, No. 4, 356, December 1960.

**KEY WORDS:** Secular Trends, Stature

Evidences of increases in the average stature of the U.S. military population are reviewed from data available in the literature. It may be concluded that average stature in the U.S. military population did not change appreciably between the Civil War and World War I. However, it is apparent that average stature in the military population increased some 3/4ths of an inch between World War I and World War II. [Abstract]

- 86 Newman, Russell W. A PRELIMINARY REPORT ON A LONGITUDINAL GROWTH STUDY OF COLLEGE MEN. (Paper presented at the 28th annual meeting, American Association of Physical Anthropologists, Madison, WI, May 1959). American Journal of Physical Anthropology, N.S. Vol. 18, No. 4, 356, December 1960.

KEY WORDS: Age Changes, Civilians, Growth, Longitudinal Study, Secular Trends, Stature

A two-year longitudinal growth study was carried out by three universities, one eastern, one midwestern, and one far western, under contract with the Quartermaster Corps. Stature and other physical measurements were collected on subjects at roughly six-month intervals. Preliminary analysis of only the stature data in relation to the chronological age of the subjects showed a pattern which differs markedly from all known age-stature series in that average stature was inversely proportional to age. In spite of this, the growth records indicate that stature increase over the two-year span was also inversely proportional to age. If the data from these three universities are accepted, some revisions of our concepts of population changes in stature during this century and prediction of growth rates seem required. [Abstract]

### 1961 PUBLICATIONS

- 87 White, Robert M. **THE ANTHROPOMETRY OF ARMY AVIATORS: A PRELIMINARY REPORT.** (Paper presented at the 29th annual meeting, American Association of Physical Anthropologists, Washington, DC, May 1960). American Journal of Physical Anthropology, N.S. Vol. 19, No. 1, 100, March 1961.

**KEY WORDS:** Anthropometric Survey, Aviators, Male Anthropometry, Measurement Techniques, Pilots

An anthropometric survey of Army aviators was recently completed by the Quartermaster Corps. In this survey, measurements were obtained on a series of 500 pilots, which represents a 10 percent sample of the Army aviator population. Forty anthropometric measurements were taken on each man; these data have been analyzed for application in the design, sizing, and human engineering of clothing and equipment in the field of Army aviation. [Abstract]

- 88 White, Robert M. **ANTHROPOMETRY OF ARMY AVIATORS.** Environmental Protection Research Division Technical Report EP-150, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, June 1961. 112 pages

**KEY WORDS:** Anthropometric Survey, Aviators, Bivariate Tables, Male Anthropometry, Measurement Techniques, Pilots

Information on the body size of Army pilots is available for the first time in the form of anthropometric measurements. Including both warrant and commissioned officers, a series of 500 flyers represents a sampling of about 10 percent of the Army aviator population. The sample of Army pilots was measured at Fort Bragg, North Carolina; Fort Benning, Georgia; Fort Rucker, Alabama; and Fort Devens, Massachusetts in 1959. Consisting of some 40 body measurements, the anthropometric data have been analyzed and are presented in the form of a table of percentile distributions and 82 bivariate charts. These data may now be applied to problems in the design, sizing, and tariffing of flight clothing and specialized equipment for Army pilots, as well as to other areas of human engineering which require the use of body size information in pilot-equipment-aircraft systems.

## 1962 PUBLICATIONS

- 89 Kennedy, Stephen J., Robert L. Woodbury, and Herman Madnick. **DESIGN AND DEVELOPMENT OF NATURAL HAND GLOVES.** Clothing and Equipment Development Branch Series Report No. 33, U.S. Army Quartermaster Research and Engineering Center, Natick, MA, July 1962. 33 pages

**KEY WORDS:** Glove Sizing, Hand, Handwear, Lasts, Male Anthropometry

This report describes and discusses a process in which master model hands and hand forms were developed. Three pairs of master model hands, designated as sizes small, medium, and large, were sculpted. The hands were modeled in a relaxed position with the palms and fingers in a natural, curved shape. Following this, metal dipping forms and experimental gloves were fabricated. A sizing study was then conducted on a series of 285 men, and it was determined that a high percentage of the male military population could be properly fitted with the four sizes of gloves provided. Subsequently, porcelain dipping forms also were fabricated.

As a result of this work, it was concluded that the measurements of the experimental master model hand forms can be used as the bases for design and measurements of all types of dipped handwear developed by the Quartermaster Corps for use by Army personnel. Fabric lined, vinyl coated gloves can be manufactured over dipping forms based on the experimental master model hands which meet the size and design requirements of the Army. Unsupported rubber, or rubber type gloves, can be manufactured over porcelain dipping forms designed and developed by the Quartermaster Corps. These forms are available to the glove dipping industry for either military or commercial application.

### 1963 PUBLICATIONS

- 90 Newman, Russell W. and Ella H. Munro. STATURE GROWTH PREDICTION IN YOUNG MEN. (Paper presented at the 31st annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, May 1962). American Journal of Physical Anthropology, N.S. Vol. 21, No. 3, 408, September 1963.

**KEY WORDS:** Age Changes, Forensic Anthropology, Growth, Long Bones, Longitudinal Study, Male Anthropometry, Skeletal Biology, Stature, Stature Estimation

Skeletal identification by comparison of previous living height with stature calculated from long bone lengths is a common anthropological problem. The technique is complicated by a number of sources of inaccuracies: the inherent statistical error of the living stature prediction, the complicating factor of racial and sex differences, and for young individuals the question of allowances for growth since the last living height assessment. Three variables are usually considered important in making a growth correction in stature reconstruction: (1) the age of the individual, (2) whether he was short or tall, and (3) the amount of time that has transpired. A longitudinal stature study of young college men provides information on all of these variables and allows comparison with previous series which used a purely cross-sectional approach. [Abstract]

- 91 White, Robert M., and Albert Damon. SKINFOLD MEASUREMENTS OF TURKISH, GREEK, AND ITALIAN MILITARY PERSONNEL. (Paper presented at the 31st annual meeting, American Association of Physical Anthropologists, Philadelphia, PA, May 1962). American Journal of Physical Anthropology, N.S. Vol. 21, No. 3, 410, September 1963.

**KEY WORDS:** Body Fat, Foreign Anthropometry, Greek Military, Italian Military, Occupational Activities, Skinfold Measurements, Stature, Turkish Military, Weight

During the course of a NATO anthropometric survey in 1960-61, skinfold thickness measurements were obtained on some 3,350 military personnel in Turkey, Greece and Italy, including representative samples from the Army, Navy, and Air Forces in each country. This paper is a preliminary report on the skinfold measurements which have been utilized for an estimation of the amount of body fat.

The sample from Turkey showed the lowest means for stature, weight, and percent body fat; the Greek sample was intermediate; and the Italian sample showed the highest means for stature, weight, and percent body fat. Jet pilots were found to be the oldest and heaviest group in each country, as well as the group having the most body fat. Italian and Greek Air Force cadets were the tallest samples, as well as the youngest. While showing moderately high mean weights, these young men were relatively low in body fat, thus indicating a generally muscular build. The lowest mean weights and the lowest amounts of body fat were found in Turkish Air Force cadets and Turkish Army personnel.

Skinfold thicknesses measured at various sites on the body during the NATO survey are further discussed and compared with similar data on samples from the United States military population. [Abstract]

- 92 Newman, Russell W. A SIMPLIFIED TECHNIQUE FOR ASSESSING COLD ACCLIMATIZATION. (Paper presented at the 32nd annual meeting, American Association of Physical Anthropologists, Boulder, CO, May 1963). American Journal of Physical Anthropology, N.S. Vol. 21, No. 3, 426, September 1963.

KEY WORDS: Cold Acclimatization, Cold Stress, Shivering

The eventual onset of gross body shivering as the result of a cold exposure is a well-known phenomenon. The time of onset and the frequency of the shivers are proportional to the level of cold exposure, the extent of the subject's cold acclimatization, and the individual patterns of the subject's cold response. This paper presents data from three studies designed to validate a technique whereby the number of shivers per standard cold exposure are recorded and integrated with short bursts of radiant heat for the purpose of allowing only sufficient rewarming to prevent the shivers from becoming continuous. Data from the same test, given at different ambient temperatures, from before and after studies of a group of artificially cold acclimatized subjects, and seasonal changes throughout a yearly cycle, will be presented. [Abstract]

- 93 White, Robert M. SKINFOLD THICKNESS MEASUREMENTS. Chapter 5 in: H.T.E. Hertzberg, Edmund Churchill, C. Wesley Dupertuis, Robert M. White, and Albert Damon. ANTHROPOMETRIC SURVEY OF TURKEY, GREECE, AND ITALY. AGARDograph 73, The Macmillan Company, New York, NY, 1963.

**KEY WORDS:** Body Fat, Foreign Anthropometry, Greek Military, Italian Military, Skinfold Measurements, Turkish Military

Skinfold thickness data were obtained on Turkish, Greek, and Italian military personnel during the NATO anthropometric survey of 1960-1961. Skinfold thickness measurements at four sites on the body (subscapular, triceps, juxta-nipple, and mid-axillary line — xiphoid) were utilized to calculate estimated body fat, according to the equations of Pascale et al. (1956), and Keys and Brozek (1953).

The data obtained from anthropometric and skinfold measurements during the NATO survey indicate a general progression in body size (based on height, weight, and percent of body fat) from Turkey to Greece to Italy. Minimal skinfold thicknesses are found in measurements of the subsample of Turkish soldiers; hence Turkish troops are estimated to have the lowest mean percentage of body fat (8.0 percent) of any group measured in the NATO survey. This investigation of skinfolds and body fat indicates that Turkish military personnel tend to be relatively lean in build; that Italian military personnel in general are inclined to somewhat more fatness; and that Greek military personnel are intermediate between their Turkish and Italian counterparts in body fat.

## 1964 PUBLICATIONS

- 94 White, Robert M. **ANTHROPOMETRIC SURVEY OF THE ROYAL THAI ARMED FORCES.** (Sponsored by the Advanced Research Projects Agency)  
U.S. Army Natick Laboratories, Natick, MA, June 1964. 62 pages

**KEY WORDS:** Anthropometric Survey, Foreign Anthropometry, Male Anthropometry, Measurement Techniques, Royal Thai Armed Forces, Stature, Summary Statistics, Thai Military, Weight

An anthropometric survey of military personnel of the Armed Forces of Thailand was conducted between October, 1962 and March, 1963. The survey was sponsored by the Advanced Research Projects Agency, Washington, DC and was authorized by ARPA Memorandum of July 27, 1962, Subject: Anthropometry Research in Southeast Asia.

Body measurements were obtained on a total series of 2,950 men, consisting of 2,010 of the Royal Thai Army, 610 of the Royal Thai Marine Corps and 330 of the Royal Thai Air Force. Fifty-two measurements were made on each individual. The anthropometric data have been analyzed and are presented in this report in the form of statistical values.

It was found that the average height and weight of Thai military personnel were equivalent to the 5th percentile values of height and weight for United States soldiers. The average Thai soldier is about four inches shorter in stature and 30 pounds lighter in weight than the average United States soldier.

The results of the survey, which provide information on the body size of Thai military personnel, may be utilized in the engineering design and sizing of clothing and equipment intended for use by the Royal Thai Armed Forces.

- 95 White, Robert M., John L. Kobrick, and Theodore R. Zimmerer. **REFERENCE ANTHROPOMETRY OF THE ARCTIC-EQUIPPED SOLDIER.**  
Technical Report EPT-2, U.S. Army Natick Laboratories, Natick, MA, August 1964. 23 pages

**KEY WORDS:** Arctic Wear, Clothed Anthropometry, Human Engineering, Work Station Design

Space in many military vehicles which can be allotted to the operator and other personnel is becoming ever smaller as mechanical and protective requirements occupy more of the space. This report is intended to help the equipment designer to make maximum use of the

available personnel space by providing accurate information on the body size of troops dressed in the bulkiest items of Army clothing. Nude body measurements do not accurately serve this purpose because they force the designer to estimate the volume of the clothing.

Data are presented on the body dimensions for the size range of the Army population dressed in the Army arctic clothing ensemble. The information is presented in tabular form, accompanied by diagrams denoting the exact location of the specific dimensions.

- 96 White, Robert M. **ANTHROPOMETRY OF U.S. ARMY AVIATORS.** (Paper presented at the Tenth Annual U.S. Army Human Factors Research and Development Conference, U.S. Army Aviation Center, Fort Rucker, AL, October 1964). Proceedings, Tenth Annual U.S. Army Human Factors Research and Development Conference, Fort Rucker, AL, (pp. 147-153), October 1964

**KEY WORDS:** Age Changes, Anthropometric Survey, Aviators, Body Fat, Male Anthropometry, Occupational Activities, Pilots, Skinfold Measurements

In the late 1950's, an increasing number of research and development problems in human engineering were arising in Army aviation. Some of the immediate design problems involved flight helmets, armor, seating, survival kits, and such items of equipment. The lack of any specific information on the range of body size in the Army aviator population became increasingly acute and embarrassing. In order to fill this gap in our knowledge, an anthropometric survey of Army aviators was proposed.

The survey was carried out in 1959 by measuring 500 Army pilots, representing at that time about a 10 percent sample of the Army aviation population. Pilots were measured at Fort Bragg, North Carolina; Fort Benning, Georgia; Fort Rucker, Alabama; and Fort Devens, Massachusetts. The series consisted of 72 percent commissioned officers and 28 percent warrant officers and included both fixed and rotary-wing pilots. Background information recorded on the subjects included birthplace, age, aeronautical designation, parachutist designation, aeronautical qualification (rating), number of years since rated, and combat flying experience. This type of information made it possible to describe the sample in detail with respect to qualification and experience.

The anthropometric aspect of the survey essentially consisted of taking 41 body measurements on each man. The body measurements included various standing and sitting heights, lengths, breadths, and circumferences, as well as some measurements of the head, face, hands, and feet. Three skinfold thickness measurements also were taken in order to permit an estimate of body fat.

The Army pilots averaged 30.25 years of age, as compared with 27.9 years for the Air Force flying personnel series, and 24.3 years for the standard Army anthropometric sample. The Army flyers thus averaged about 2 years older than the Air Force and 6 years older than the Army as a whole. These age differences reflect the differences found in body size. The Army pilots were found to be 69.5 inches tall and to weigh 165.8 pounds on the average. They were thus one-half inch taller and two pounds heavier than Air Force flying personnel, and one inch taller and eleven pounds heavier than the Army in general. Other body proportions are correspondingly larger or greater.

- 97 White, Robert M. **ANTHROPOMETRIC SURVEY OF THE ARMED FORCES OF THE REPUBLIC OF VIETNAM.** (Sponsored by the Advanced Research Projects Agency) U.S. Army Natick Laboratories, Natick, MA, October 1964. 66 pages

**KEY WORDS:** Anthropometric Survey, Foreign Anthropometry, Male Anthropometry, Measurement Techniques, Stature, Summary Statistics, Vietnamese Military, Weight

An anthropometric survey of military personnel of the Republic of Vietnam was conducted between 28 May and 1 July, 1963. The survey was sponsored by the Advanced Research Projects Agency, Washington, DC, and was authorized by ARPA Order No. 267, Amendment No. 6, dated 8 May 1963.

Body measurements were obtained on a total series of 2,129 men, consisting of 1,225 of the Army, 299 of the Navy, 301 of the Marine Corps, and 304 of the Air Force. Fifty-one measurements were made on each individual. The anthropometric data have been analyzed and are presented in this report in the form of statistical values.

It was found that the 50th percentile value for the stature of Vietnamese military personnel is equivalent to the 2nd percentile value for United States soldiers, while the 50th percentile value for the weight of Vietnamese personnel is less than the 1st percentile for United States soldiers. The average Vietnamese soldier is about five inches shorter in stature and 43 pounds lighter in weight than the average United States soldier.

The results of the survey, which provide information on the body size of Vietnamese military personnel, may be utilized in the engineering design and sizing of clothing and equipment intended for use by the Armed Forces of the Republic of Vietnam.

- 98 White, Robert M. **MILITARY ANTHROPOMETRY IN SOUTHEAST ASIA.**  
(Paper presented at the 33rd annual meeting, American Association of Physical Anthropologists, Mexico City, D.F., Mexico June, 1964). American Journal of Physical Anthropology, N.S. Vol. 22, No. 4, 506, December 1964.

**KEY WORDS:** Anthropometric Survey, Foreign Anthropometry, Male Anthropometry, Royal Thai Armed Forces, Thai Military, Vietnamese Military

Anthropometric surveys of military personnel were conducted in the Kingdom of Thailand in 1962 and in the Republic of Vietnam in 1963. They were carried out under the sponsorship of the Advanced Research Projects Agency, United States Department of Defense, Washington, DC.

During the survey in Thailand, 2,950 men of the Royal Thai Armed Forces were measured, including samples from the Army, Marine Corps, and Air Force. The survey in the Republic of Vietnam included a series of 2,130 men of the Army, Navy, Marine Corps, and Air Force. In both surveys the measuring was carried out by teams of native military personnel. Approximately 50 body measurements were made on each individual.

Besides summarizing and discussing the results of the surveys, the anthropometry of military personnel in other Asian countries will be commented upon. [Abstract]

### 1965 PUBLICATIONS

- 99      Burse, Richard L. USAF SIZE EXTRA-LARGE FLIGHT  
HELMET: COMPARISON OF DIMENSION SPECIFICATIONS WITH  
ANTHROPOMETRIC DATA. Report No. EPR-6, U.S. Army  
Natick Laboratories, Natick, MA, January 1965.  
7 pages

KEY WORDS:    Aircrew, Aviators, Flight Helmet, Headgear, Pilots

Four internal dimension specifications of the U.S. Air Force design for the size extra-large flight helmet were compared with pertinent anthropometric data from the U.S. Army pilot and the U.S. Air Force aircrewman populations in order to determine the ranges of pilots properly accommodated. Three of the specified dimensions were found to properly accommodate the 99.9th percentile and maximum values of both flying populations. One dimension was inadequate for the maximum values of both populations. Suggested modifications to increase the range accommodated by this dimension are discussed, as are other suggestions to improve fit of the helmet.

## 1966 PUBLICATIONS

- 100 White, Robert M. **MAN IN TERRESTRIAL ENVIRONMENTS: THE ROLE OF MILITARY ANTHROPOMETRY IN SYSTEM DEVELOPMENT.** (Paper presented at a symposium, 35th annual meeting, American Association of Physical Anthropologists, Berkley, CA, April 1966). American Journal of Physical Anthropology, N.A. Vol. 25, No. 2, 216-117, September 1966.

**KEY WORDS:** Anthropometric Survey, Anthropometry, Applied Physical Anthropology, Clothing Design, Clothing Sizing, Foreign Anthropometry, Human Engineering, Human Factors, Tariff Derivation

An important concept in the area of military research and engineering is represented by the so-called systems approach. According to this concept, the man or the individual soldier, together with his equipment, whether it be a machine he is operating or personal equipment he is wearing or using, is considered to be a man/equipment system. A basic requirement for the effective use and operation of such a system is that the man and the equipment be compatible.

The successful achievement of such compatibility depends upon the satisfactory design and engineering of the equipment in order to provide the best possible utilization and acceptability by the soldier in performing his mission.

Since anthropometric data constitute a basic requisite for defining the elements of body size in the human engineering of man/equipment systems, anthropometry represents an essential input to the development of such systems. Since effective human engineering requires the use of body size data on the specific population for which the equipment is intended, military anthropometry is one source of the information necessary for the design and sizing of equipment and materiel to be used by the Armed Forces.

Anthropometry is the measurement of the human body. Anthropometric data may be collected by measuring large, representative samples of the military population. Through the compilation, processing, analysis and synthesis of such data, it is possible to provide a metric description of the military population for general use in the design and human engineering of military equipment and materiel, and also for specific application in the design, sizing and tariffing of clothing and individual equipment.

Several anthropometric surveys of military personnel have been conducted since 1946. New surveys of all the U.S. Armed Forces are now in progress. These will be reviewed and the availability of such anthropometric data will be discussed.

Anthropometric data on various foreign military populations have become available in recent years. Reference will be made to recent surveys in Turkey, Greece, Italy, Japan, Thailand, Vietnam, and Korea.

Utilization and application of anthropometric data on both U.S. and foreign military populations within the framework of the Army human factors program will be explained and discussed. [Abstract]

- 101 Burse, Richard L. **HUMAN FACTORS REQUIREMENTS FOR THE DESIGN OF HELICOPTER AIRCREWMAN'S GEAR AND GROIN PROTECTIVE UNITS.**  
Technical Report 67-28-PR, U.S. Army Natick Laboratories, Natick, MA, September 1966. 11 pages

**KEY WORDS:** Aircrew, Armored Protective Seat, Body Armor, Combat Vehicles, Human Engineering, Human Factors, Work Station Design

The ever-increasing combat role of helicopters requires that particular attention be devoted to the man-machine interface between the aircraft and the operating crew. This report summarizes the major human factors requirements to be considered in the design of rigidly armored protective seat and groin units for crew chiefs and door gunners of UH-1 series helicopters. Quantitative design criteria are specified to provide further assistance to designers.

The most important human factors requirements for the design of rigidly armored seat and groin protective units for seated helicopter aircrew are discussed. Included are requirements for preventing interference with mission performance, reducing fatigue, and providing a compatible, safe and somewhat comfortable working environment for fully-equipped aircrew personnel. Quantitative design criteria for dimensions, contours, cushioning, and location of the seat and groin protective units are specified.

### 1967 PUBLICATIONS

- 102 Burse, Richard L. HUMAN FACTORS EVALUATION OF BODY-SUPPORTED AIRCREWMAN'S BUTTOCKS AND CROTCH PROTECTIVE UNIT; COMPARISON OF TWO HEIGHTS OF CROTCH PROTECTOR AND THREE SUSPENSION SYSTEMS. Technical Report 68-4-PR, U.S. Army Natick Laboratories, Natick, MA, July 1967. 24 pages

KEY WORDS: Aircrew, Body Armor, Fit Test, Human Engineering, Human Factors, Work Station Design

This report is the second in a series concerned with the human factors implications of body armor for U.S. Army aircrew personnel. This series is to assist the designer of body armor by specifying design criteria, human factors evaluation methods, and test results.

The research described in this report evaluates one concept for lower body protection of aircrew personnel, wherein the protective unit is attached to the user's body rather than to the aircraft seat structure.

The research described was an evaluation of body-supported aircrew's buttocks and crotch protective units in which two heights of crotch protector and three different suspension systems were compared with respect to fit, comfort, ease of use, estimated length of time the system could be used, and the adequacy of several dimensions of the protective units.

In general, both types of protective units and all three suspension systems were equally satisfactory. However, one type of suspension system and one height of crotch protector were significantly easier to use, while both crotch protectors were too wide. Subjects desired that the longer crotch protector be shortened and the shorter crotch protector be lengthened to approximately the same length. This desired change apparently was based on factors other than physical discomfort.

103 Hart, Gary L., George E. Rowland, and Robert Malina.  
ANTHROPOMETRIC SURVEY OF THE ARMED FORCES OF THE REPUBLIC OF  
KOREA. Contract Report (Contract DA19-129-AMC-480(N)), Rowland  
and Company, Inc., Haddonfield, NJ Technical Report 68-8-PR, U.S.  
Army Natick Laboratories, Natick, MA, July 1967. 104 pages

KEY WORDS: Anthropometric Survey, Equipment Evaluation, Human  
Factors, Korean Military, Male Anthropometry, Measurement  
Techniques

Anthropometric and equipment evaluation surveys of the military personnel of the Republic of Korea were conducted between May and November of 1965. Body measurements and equipment evaluation data were obtained on a series of 3,747 men (3,249 Army, 190 Air Force, 141 Navy, and 167 Marine). Fifty-nine body measurements and 20 equipment evaluation measures were made on each individual.

Of the 59 body measurements taken on Korean soldiers, 39 were directly comparable with data which had been previously collected on U.S. troops. The differences between means of the two samples were statistically significant for 30 of the measures. The means of data from U.S. troops exceeded those for Korean soldiers on 33 of the measures, indicating larger physical size in almost all dimensions. Korean troops expressed themselves on the question: "Insofar as 'fit' is concerned, the (equipment) supplied by the U.S. Army is...." on a seven point continuum ranging from "excellent" to "very poor". Respondents filled out a questionnaire containing general statements described above, as well as more specific items relating to grasping, reaching, and positioning the equipment as far as comfort and effectiveness were concerned. Subjects rated the smaller, lighter equipment favorably with respect to ease of handling, and reported considerable difficulty using larger weapons and equipment.

### 1968 PUBLICATIONS

- 104 Burse, Richard L., and William D. Cahill. **COMFORT AND STABILITY RATINGS FOR LINCLOE HELMET AND SUSPENSION SYSTEMS COMPARED TO THOSE FOR STANDARD ITEMS.** Technical Report 69-3-PR, U.S. Army Natick Laboratories, Natick, MA, July 1968. 30 pages

**KEY WORDS:** Fit Test, Headgear, Human Factors, LINCLOE Helmet

The research described in this report compares the comfort and stability of the standard Army system for head protection with an experimental system developed under the Lightweight Individual Clothing and Equipment (LINCLOE) concept. This concept is envisioned to drastically reduce the burden imposed on the front-line soldier by selectively reducing the weight and increasing the durability of individual clothing and equipment. The human factors research accompanying this effort is intended to assist the designers of LINCLOE clothing and equipment by specifying design criteria, human factors evaluation methods, and test results.

A sample of sixteen test subjects awarded comfort and stability ratings to the standard U.S. Army M-1 steel helmet and suspension system, one experimental LINCLOE polycarbonate helmet, and three experimental LINCLOE helmet suspension systems. All occurrences of subjects' touching or readjusting the helmet system were recorded, as were subjective ratings for ease of adjustment of the suspension system, overall comfort, helmet warmth, location of chinstrap, pressure produced by the suspension system, annoyance produced by the suspension system, interference with hearing, noise produced by the helmet/suspension combination, and stability when running, jumping, throwing, crawling, digging, and crawling under a wire obstacle. After scaling, scores and subjective ratings for the four suspension systems and two helmets were analyzed for significant differences.

The standard M-1 steel helmet was generally rated inferior to the experimental polycarbonate helmet for comfort and stability, while the standard M-1 suspension system was generally rated superior to all experimental suspension systems for comfort and stability. One experimental suspension system closely approached the stability of the M-1 suspension; however, a different experimental suspension somewhat less closely approached the comfort of the M-1 suspension. Of the performance tasks utilized in the study, grenade throwing and low crawling appeared to best identify suspension systems which were unstable enough to tip over the forehead and produce visual restriction.

105 Burse, Richard L., William D. Cahill, and Earl P. Summers.  
**COMFORT AND STABILITY RATINGS FOR PROTOTYPE LINCLOE TITANIUM  
HELMET SYSTEM.** Technical Report 69-20-PR, U.S. Army Natick  
Laboratories, Natick, MA, August 1968. 11 pages

**KEY WORDS:** Fit Test, Headgear, Human Factors, LINCLOE Helmet

The research described in this report compares the comfort and stability of the standard Army system for head protection with an experimental system developed under the Lightweight Individual Clothing and Equipment (LINCLOE) concept. This concept is envisioned to drastically reduce the burden imposed on the front-line soldier by selectively reducing the weight and increasing the durability of individual clothing and equipment. The human factors research accompanying this effort is intended to assist the designers of LINCLOE clothing and equipment by specifying design criteria, evaluation methods, and test results.

Six test subjects awarded comfort and stability ratings for the standard 3.16-pound M-1 steel helmet system and an experimental 1.53-pound LINCLOE one-piece titanium helmet system. The suspension system of the experimental helmet was attached directly to the titanium ballistic shell, obviating the need for a helmet liner.

Subjective ratings were recorded for: ease of adjustment of the suspension system, comfort, helmet warmth, location of chinstrap, interference with hearing, noise produced by the helmet, interference with aiming the carbine, and stability when running, jumping, grenade throwing, and crawling under a wire obstacle. After scaling, differences between the ratings for the experimental and the standard systems underwent t-testing for significance. There was only one significant difference between the two systems: the experimental system was rated as more stable when throwing grenades. It is suspected that the M-1 helmet was rated as inferior on this task because it tipped forward, interfering with vision, while the experimental system did not.

### 1969 PUBLICATIONS

- 106 White, Robert M. **CHANGES IN BODY SIZE IN AMERICAN MEN.** Paper presented at the 3rd Annual Technical Conference, Apparel Research Foundation, Washington, DC, October 1969.

**KEY WORDS:** Body Size, Clothing Sizing, Male Anthropometry, Secular Trends

Are American men getting larger? Is the general body size of the American male increasing? Questions of this type have been frequently asked in recent years. The matter of body size is not only one of general interest, but actually one of considerable importance, particularly with respect to clothing and apparel. Therefore, a discussion of changes in body size in American men, based upon facts and figures, rather than impressions and opinions, may prove both interesting and useful.

Unfortunately, very few reliable anthropometric data are available on the U.S. civilian population. However, a large amount of information on body size in the military population has been accumulated, particularly during the past twenty years.

It is concluded that an analysis of U.S. Army anthropometric data between 1946 and 1966 does indicate some increase in body size in American men, but that, on the average, these increases are generally rather small. A much more important conclusion of this study, however, is that shifts in the distribution of body sizes within the population will result in a requirement for relatively larger numbers or quantities of the larger clothing sizes.

## 1970 PUBLICATIONS

- 107 White, Robert M. THE UTILIZATION OF MILITARY ANTHROPOMETRY FOR AIRCRAFT COCKPIT DESIGN. In: Problems of the Cockpit Environment (pp. 15-1 — 15-9), Advisory Group for Aerospace Research and Development Conference Proceedings No. 55, NATO-AGARD, March 1970. (Papers presented at the AGARD Avionics Panel XVth Technical Symposium, Amsterdam, the Netherlands, November 1968.)

KEY WORDS: Anthropometry, Aviators, Body Size, Cockpit Design, Human Engineering, Occupational Activities, Pilots

Since anthropometric data constitute a basic requisite for defining the elements of body size in the human engineering of man/equipment systems, anthropometry represents an essential input to the development of such systems in order to achieve compatibility between the man and his equipment. The analysis and evaluation of anthropometric data are discussed in this paper, with reference to newly available data on the U.S. military population. It is shown that the U.S. data indicate distinct differences in body size between flying and non-flying military personnel, primarily due to a marked difference in age. Finally, some general observations are made regarding the applications of anthropometric data in aircraft cockpit design.

### 1971 PUBLICATIONS

- 108 Kennedy, Stephen J., and Robert M. White. ANTHROPOMETRIC SURVEY OF THE IMPERIAL IRANIAN ARMED FORCES: PHASE III — TECHNICAL SUMMARY, AND COMBAT BOOT STUDY PROJECT — TECHNICAL SUMMARY. U.S. Army Natick Laboratories, Natick, MA, May 1971. 79 pages

KEY WORDS: Anthropometric Survey, Clothing Sizing, Combat Boot, Footwear, Foreign Anthropometry, Iranian Military, Lasts, Male Anthropometry, Measurement Techniques, Tariff Derivation

This Technical Summary combines a report on Phase III of the Imperial Iranian Armed Forces Anthropometric Survey and the report on the Combat Boot Study project which also involves application of the anthropometric data obtained in the first two phases of the Imperial Iranian Armed Forces Anthropometric Survey.

In accordance with a request made by IIADF, an anthropometric survey was undertaken by the Combat Research and Evaluation Center at the direction of the Vice Chief of the Supreme Commander's Staff, Lt. General Fereidun Djam. The main objective of the survey was to provide the Imperial Iranian Armed Forces with a basis for determining how to improve their uniforms and tariffs.

The collection of data for this program, undertaken by CREC in consultation with the Research Triangle Institute as part of an ARPA program, was completed in 1969.

The application of anthropometric data is a highly complex task involving the generation of patterns in the case of clothing, and footwear lasts in the case of boots. Because of similarities in body proportions and other common aspects of anthropometric data, it was apparent that there was a good chance that a relationship could be established between the anthropometric measurements of IIADF and U.S. military personnel, which could make possible the utilization of U.S. experience in the development of patterns and lasts without the need for initiation of totally new projects.

Preliminary examination of IIADF data indicated that such correlation was possible. This was pointed out by Dr. Kennedy upon his visit to Iran 9-20 April 1971, to representatives both of ARMISH-MAAG and the IIADF.

It was stated that a technical summary would be made in which the application of the anthropometric data generated in the Iranian study would be applied to patterns and lasts in a way in which this information could be used by the Imperial Iranian Armed Forces for the stated objectives. This report, accordingly, includes the technical

summary on the application of the anthropometric data to uniforms and to combat footwear, with appropriate recommendation as to actions which could be taken to accomplish the original objectives of the anthropometric survey.

- 109 White, Robert M., and Edmund Churchill. **THE BODY SIZE OF SOLDIERS: U.S. ARMY ANTHROPOMETRY — 1966.** Technical Report 72-51-CE, U.S. Army Natick Laboratories, Natick, MA, December 1971. 329 pages

**KEY WORDS:** Anthropometric Survey, Body Size, Male Anthropometry, Measurement Techniques, Secular Trends, Summary Statistics

As a part of the U.S. Armed Forces anthropometric survey of 1966, a sample of 6,682 Army men was measured, including basic trainees, infantry, armored crewmen, and aviation personnel. Seventy body measurements were taken on each subject. The anthropometric data from this survey are presented and discussed. These new data represent the first major updating of body size information on U.S. Army personnel since the Army anthropometric survey of 1946. Changes in the body size of Army men between 1946 and 1966 are discussed and the Army data are compared with anthropometric data from other services.

- 110 Churchill, Edmund, John T. McConville, Lloyd L. Laubach, and Robert M. White. **ANTHROPOMETRY OF U.S. ARMY AVIATORS — 1970.** Contract Report (Contract DAAG 17-70-C-0055), Anthropology Research Project, Yellow Springs, Ohio. Technical Report 72-52-CE, U.S. Army Natick Laboratories, Natick, MA, December 1971. 335 pages

**KEY WORDS:** Aircrew, Anthropometric Survey, Aviators, Correlation Coefficients, Male Anthropometry, Measurement Techniques, Occupational Activities, Pilots, Summary Statistics

This report describes an anthropometric survey of U.S. Army aviators conducted at Fort Rucker, Alabama in 1970. Data for 85 body size measurements and for several variables describing the socio-military background of the survey subjects were gathered on a sample of 1,482 flying personnel. Statistical summaries are presented for each measurement for the entire sample and for five subseries: enlisted aviators (crew chiefs, mechanics, door gunners), warrant officer and warrant officer candidate trainees, warrant officer rated pilots, commissioned trainees, and commissioned pilots. Summary statistics and percentiles for 80 anthropometric indices and for some 73 anthropometric variables computed from the measured dimensions are given, as is the correlation matrix for the measured variables and age.

### 1973 PUBLICATIONS

- 111 Kennedy, Stephen J., Ralph Goldman, and John Slauta. **THE CARRYING OF LOADS WITHIN AN INFANTRY COMPANY.** Technical Report 73-51-CE, U.S. Army Natick Laboratories, Natick, MA, May 1973. 70 pages (Anthropometric data prepared by Robert M. White)

**KEY WORDS:** Infantry, Load Carrying Equipment, Occupational Activities

The carrying of loads by the infantry involves four distinct problems:

- a. The capacity of the load-carrying equipment, particularly in the pack, in relation to the requirements of various combat missions.
- b. The weight of the load, in relation to the physiological limitations of the soldier.
- c. The carrying of portable equipment assigned by the TO&E to various military occupational specialists in the infantry company, and other special items of organizational equipment.
- d. How the load can best be distributed and carried.

This study has been intended to bring these problems into perspective, both in relation to what has been done in the past and what is currently in progress, as well as to indicate some special aspects that should be of concern to designers of equipment intended to be portable.

#### 1974 PUBLICATIONS

- 112 Claus, William D., Jr., Lawrence R. McManus, and Philip E. Durand. **DEVELOPMENT OF HEADFORMS FOR SIZING INFANTRY HELMETS.** Technical Report 75-23-CEMEL, U.S. Army Natick Laboratories, Natick, MA, June 1974. 31 pages

**KEY WORDS:** Head, Head Form, Head Measuring Device, Headgear, Helmet Sizing

A new technique for defining and measuring head shapes was developed and applied in the fabrication of a set of first generation plaster headforms. The design of a unique head measuring device is reported. The device is a clear polycarbonate hemisphere on which are mounted twenty-seven moveable mechanical probes. The hemisphere is placed over a subject's head, and the probes are moved to contact the head and thus define head shape. The probe data from a population of Army men were reduced statistically to yield generalized head shapes. The feasibility of combining this probe technique with classical anthropometric head measurements to yield generalized head shapes of various sizes was demonstrated. A set of first generation headforms was sculpted using specific probe data. Improvements and extensions of the present study are indicated.

### 1975 PUBLICATIONS

- 113 McManus, Lawrence R., William D. Claus, Jr., Philip D. Durand, and Michael Kulinski. **VERIFICATION FIT TEST OF THREE-SIZE INFANTRY HELMET.** Technical Report 75-79-CEMEL, U.S. Army Natick Development Center, Natick, MA, January 1975. 44 pages

**KEY WORDS:** Fit Test, Headgear, Helmet Sizing, Tariff Derivation

The object of this report is to present the statistical analysis of a fit test of a three-size helmet system. The test was conducted at Fort Devens, MA, during July, 1974. Four hundred and three officers and enlisted men of the 10th Special Forces served as subjects.

The anthropometric measurements taken and recorded for each subject's head included circumference, length, breadth, height, glabella to vertex, biaural breadth (ear to ear), and menton to vertex.

Each subject was given a helmet size designation according to sizing criteria based on circumference, length, and breadth. Each subject was then fitted with a clear polycarbonate helmet shell (with suspension system) of the designated size. Each shell had 13 numbered probe holes. The stand-off was checked by probing the distance of the shell from the head. All probe readings less than 12.7 mm were recorded on the subject's record sheet.

As a result of this fit test, it was concluded that the three-size infantry helmet system fits the U.S. Army population with a tariff of approximately 20, 50, and 30 percent for the respective sizes of small, medium, and large. The helmet system in three sizes, after a very slight modification to length and width, will have a 12.7 mm minimum stand-off at all points on the head.

- 114 White, Robert M. ANTHROPOMETRIC MEASUREMENTS ON SELECTED POPULATIONS OF THE WORLD. Chapter 3 in: Alphonse Chapanis (editor), *Ethnic Variables in Human Factors Engineering*, the John Hopkins University Press, Baltimore, MD, 1975. (Library of Congress Catalog Card No. 74-24393) (Based on papers presented at a symposium on "National and Cultural Variables in Human Factors Engineering", held at Osterbeek, The Netherlands, 19-23 June, 1972, under the auspices of the Advisory Group on Human Factors, North Atlantic Treaty Organization)

KEY WORDS: Chest Circumference, Geographical Variation, Human Engineering, Racial Variation, Sitting Height, Stature, Weight

In the efficient human engineering of man/equipment systems, information on the range of variability in human body size and proportions is of basic importance. Such information is to be found in anthropometric data on the population for which the equipment is intended. Anthropometric data on four basic body dimensions (weight, stature, sitting height, and chest circumference) are presented and discussed to illustrate the range of variability in body size to be found in diverse populations.

### 1976 PUBLICATIONS

- 115      McManus, Lawrence R., Philip E. Durand, and William D. Claus, Jr. **DEVELOPMENT OF A ONE-PIECE INFANTRY HELMET.** Technical Report 76-30-CEMEL, U.S. Army Natick Research and Development Command, Natick, MA, January 1976. 47 pages

**KEY WORDS:**    Ballistic Materials, Headgear, Helmet Sizing, Human Factors, Infantry, Transient Deformation

The Army Materiel Development and Readiness Command interlaboratory helmet development program is outlined, and the steps taken to develop a new infantry helmet are reported. The results of studies ranging from anthropometry to wearability were synthesized into a military helmet design. Studies included a mathematical sizing model, human factors compatibility evaluations, heat transfer and transient deformation measurements, suspension system designs, and ballistic materials investigations. The resulting three-size, one-piece, ballistic helmet offers significantly improved protection, fit, comfort, and stability over the standard M-1 helmet and nylon liner.

116 White, Robert M. **ANTHROPOMETRY AS A VARIABLE IN HUMAN FACTORS ENGINEERING.** (Paper presented at the 6th Congress of the International Ergonomics Association, College Park, MD, July 1976). Proceedings, 6th Congress of the International Ergonomics Association, College Park, MD, July 1976, pp. 131-135. Published by the Human Factors Society, Santa Monica, CA, July 1976. (Abstract published in Ergonomics, Vol. 19, No. 3, 361-362, May 1976).

**KEY WORDS:** Anthropometry, Applied Physical Anthropology, Ergonomics, Geographical Variation, Human Engineering, Human Factors, Racial Variation

One of the fundamental concepts in the field of human factors engineering or ergonomics is represented by the systems approach. According to this concept, the individual together with his or her equipment, whether it be personal equipment to be worn, or a machine to be operated, is considered to be a man/equipment system. A basic requirement for the efficient use and operation of such a system is that the individual and the equipment be compatible. Effective human engineering plays an important role in achieving such compatibility. Since anthropometric data constitute a basic requisite for defining the elements of body size in the human engineering of man/equipment systems, anthropometry provides an essential input in the development of such systems.

Anthropometry is the measurement of the human body. Since effective human engineering requires the use of body size data on the specific population for which the equipment is intended, military anthropometry, for example, is one important source of the information necessary for the design and sizing of equipment and materiel to be used by military forces. Similarly, anthropometric data on civilian populations are required for application in the human engineering of industrial man/equipment systems or in the design and development of products for civilian consumer use. Fortunately, more and more anthropometric data have become available in recent years, not only in the United States, but in many other countries. Even a cursory or superficial examination of these data immediately indicate very clearly that marked differences exist between populations in human body size and proportions. Anthropometric data thus serve to emphasize the ranges of variation in human body size. Although human variability has not received sufficient attention in the field of human engineering or ergonomics in the past, it cannot be ignored. More emphasis on the accommodation of human variability is necessary if we are to improve the human engineering of man/equipment systems. The purpose of this paper is to first review available sources of anthropometric data. Secondly, through the examination and discussion of several of the basic dimensions of the human body, some of the parameters of human variability will be indicated as they relate to human engineering.

### 1977 PUBLICATIONS

- 117 Laubach, Lloyd L., John T. McConville, Edmund Churchill, and Robert M. White. **ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY — 1977; REPORT NO. 1, METHODOLOGY AND SURVEY PLAN.** Contract Report (Contract DAAG 17-76-C-0010), Webb Associates, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-77/021, U.S. Army Natick Research and Development Command, Natick, MA, June 1977. 202 pages

**KEY WORDS:** Anthropometric Survey, Female Anthropometry, Measurement Definitions, Measurement Techniques

An anthropometric survey of U.S. Army women was conducted during the winter of 1976-1977 — the first such survey in 30 years. The survey was planned and carried out in response to the need for current and comprehensive body size and strength data for the women who make up an increasingly large part of the U.S. Army. The main purpose of the survey was to obtain and develop statistical data on body size, workspace parameters, and static muscle strength of U.S. Army women. During the survey, data were obtained on 128 conventional body size dimensions, 14 workspace dimensions, and 9 static strength measurements. Many of the measurements made had not been previously reported for any large-scale survey of women, military or civilian. Other measurements were selected to supplement and complement data already available to provide up-to-date information for use in the design of clothing, protective equipment, workspace and industrial equipment which women in the Army wear, use, or operate, or within which they work.

This, the first of a series of reports dealing with this survey, describes the methodology used in the conduct of the survey. Included here are an outline of the survey design, a listing of the landmarks used in defining the dimensions to be measured, and detailed descriptions of the procedures used in making each measurement.

Measurement techniques used in previous large-scale anthropometric surveys of women also are listed here. Thus this report, in addition to reporting the methodology of the present survey, constitutes a comprehensive source book of anthropometric techniques for use with women.

118 Churchill, Edmund, Thomas Churchill, John T. McConville, and Robert M. White. ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY — 1977; REPORT NO. 2, THE BASIC UNIVARIATE STATISTICS. Contract Report (Contract DAAG 17-76-C-0010), Webb Associates, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-77/024, U.S. Army Natick Research and Development Command, Natick, MA, June 1977. 287 pages

**KEY WORDS:** Anthropometric Survey, Female Anthropometry, Summary Statistics

This report, the second in a series, summarizes the univariate statistics obtained in an anthropometric survey of women in the U.S. Army conducted at the following Army posts during the winter of 1976-1977: Fort Sam Houston, Texas; Fort McClellan, Alabama; Walter Reed Medical Center, the District of Columbia; and Fort Jackson, South Carolina. This survey, carried out to satisfy the need by the U.S. Army for up-to-date data on the body sizes and strength capabilities of the women who now constitute a substantial portion of its personnel, represents the first major anthropometric survey of Army women since 1946.

Data for 69 body size measurements were obtained on a sample of 1331 women who covered wide ranges of age, rank, and military assignment. Additional data were obtained on subseries of between 200 and 300 women for: (a) other standard body size measurements, (b) workspace measurements, (c) head and face measurements, and (d) static strength measurements. Summary statistics and frequency distributions are given here of all these measurements, as well as age.

Full descriptions of the measurement techniques and the design and conduct of the survey have already appeared in the first of this series of reports. Brief definitions, illustrations of measurements, and outlines of the computational and statistical procedures used in preparing this report are included here.

119 Churchill, Thomas, Edmund Churchill, John T. McConville, and Robert M. White. ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY — 1977; REPORT NO. 3, BIVARIATE FREQUENCY TABLES. Contract Report (Contract DAAG 17-76-C-0010), Webb Associates, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-77/028, U.S. Army Natick Research and Development Command, Natick, MA, July 1977. 351 pages

**KEY WORDS:** Anthropometric Survey, Bivariate Tables, Correlation Coefficients, Female Anthropometry, Regression Analysis

In this report, the third in a series, over 300 bivariate frequency tables based on the data from the 1976-1977 anthropometric survey of U.S. Army women are presented to facilitate the use of these data by designers of clothing, equipment, and workspaces which Army women will wear or use. A bivariate frequency table of anthropometric data indicates the number or proportion of a group of individuals who fall within a particular range of values for one variable or dimension and, simultaneously, within a specified range for a second variable. Thus the bivariate table shows the range of two anthropometric measurements and the numbers or frequencies of women who have the various possible combinations of values of the two measurements.

Ninety-seven bivariate tables are presented with the dimensional data expressed in inches; in twenty-three of these the frequencies are shown in truncated form with the elimination of a few of the extreme values. The remaining 210 biviates are given with the dimensional data shown in centimeters. Coefficients of correlation, expressing the degree of relationship between the two measurements, and the regression equations for the two related measurements, also are given.

120 McConville, John T., Edmund Churchill, Thomas Churchill, and Robert M. White. ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY — 1977; REPORT NO. 5, COMPARATIVE DATA FOR U.S. ARMY MEN. Contract Report (Contract DAAG 17-76-C-0010), Webb Associates, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-77/029, U.S. Army Natick Research and Development Command, Natick, MA, July 1977. 237 pages

KEY WORDS: Anthropometric Survey, Bivariate Tables, Female Anthropometry, Gender Variation, Male Anthropometry, Summary Statistics

This report, the fifth in a series which deals with the results of an anthropometric survey of 1,331 U.S. Army women, presents comparable data resulting from the measurement of 287 Army men. The opportunity to secure measurements on male subjects made by the same technicians at the same time and place, and using precisely the same measuring techniques, provided a unique source of comparative data for the design of Army clothing, equipment, and workspaces which, increasingly, must accommodate the wide range of sizes represented by both sexes.

The men's survey was carried out at Fort Jackson, South Carolina, in early 1977. The subjects represented a homogeneous group, chiefly trainees with a median age of about 19 years. The sample was composed of approximately two-thirds Whites, one-third Blacks, and a small fraction of Asians.

This report describes the conduct of the men's survey and includes the univariate summary statistics and frequency tables resulting from it. Data obtained in the survey included 44 of the 69 body size measurements made on Army women and 13 of an additional 24 standard body dimensions measured on the women, as well as three identical subseries of workspace, head and face, and static strength measurements. Also provided are 51 selected bivariate frequency tables.

121 Churchill, Edmund, P. Kikta, and Thomas Churchill. THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUMES I-V. Technical Report AMRL-TR-77-1, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, October 1977.

**KEY WORDS:** Anthropometric Survey, Correlation Coefficients, Female Anthropometry, Male Anthropometry, Measurement Definitions, U.S. Air Force

This report describes the contents of Volumes I-V of the AMRL Anthropometric Data Bank Library. Volumes I-IV consist of the data from four major USAF anthropometric surveys: the 1950 and 1967 surveys of flying personnel, the 1968 survey of USAF women, and the 1965 survey of male personnel. Volume V contains correlation coefficients based on these surveys, the 1946 survey of Army female separatees, the Health Examination Survey of 1960-62, and the law enforcement officer survey of 1974.

Included are a description of the tape formats, definitions of the measurement variables, and a listing of extreme values for each tape. Names and serial numbers of all subjects have been omitted to preserve the confidential nature of the records.

122 White, Robert M., and Edmund Churchill. UNITED STATES MARINE CORPS ANTHROPOMETRY. Technical Report NATICK/TR-78/021, U.S. Army Natick Research and Development Command, Natick, MA, December 1977. 298 pages

KEY WORDS: Anthropometric Survey, Body Size, Comparative Anthropometry, Male Anthropometry, U.S. Marine Corps

An anthropometric survey of U.S. Marine Corps men was carried out in January and February, 1966. During the survey, seventy body measurements were made on a total sample of 2,008 Marines; 1,003 subjects were measured at Camp Lejeune, North Carolina and 1,005 subjects were measured at Camp Pendleton, California. The resulting anthropometric data are presented in detail and discussed in this report.

The U.S. Marine Corps anthropometric data were compared with U.S. Army anthropometric data, and it was found that Marine Corps personnel are very similar to U.S. Army personnel in body size and proportions.

The U.S. Armed Forces anthropometric surveys of 1966, of which the Marine Corps survey was a part, represented the first major updating of anthropometric data on the U.S. military population in some twenty years. These surveys also provided, for the first time, standard anthropometric data for all of the U.S. Armed Forces.

Body size information, in the form of anthropometric data, is required as a basis for design criteria in the development of military equipment and materiel. Information on the range of variability in body size and proportions within the military population is necessary for the design, sizing, and tariffing of military clothing and individual equipment. Anthropometric data provide a basic input for the design and human engineering of military equipment and materiel. The Marine Corps anthropometric data should be of wide use and application in the design, sizing, and human engineering of clothing, personal equipment, and other materiel intended for use by the United States Marine Corps.

### 1978 PUBLICATIONS

- 123 White, Robert M., and Gregory DeSantis. **THE IMPACT OF FEMALE ANTHROPOMETRY ON THE U.S. ARMY.** (Paper presented at the Army Science Conference, West Point, NY, June 1978 (AD A056 493)). Army Science Conference Proceedings, 20-22 June 1978, Volume III, 325-336. Department of the Army, Deputy Chief of Staff for Research, Development and Acquisition, Washington, DC

**KEY WORDS:** Anthropometric Survey, Body Size, Clothing Sizing, Female Anthropometry, Gender Variation, Human Engineering

During the past 30 years, several major anthropometric surveys have been carried out in the U.S. Army. Large numbers of both men and women were measured in 1946, at the end of World War II. Army men were measured again in 1966, while Army aviation personnel were measured in 1959, and again in 1970. The most recent survey of Army women was made in 1977. A small sample of men also was measured in order to obtain directly comparable data. The importance of the latter anthropometric survey of U.S. Army women is the subject of this paper.

An essential element in the effective development of Army clothing, equipment, and other materiel is the availability of information on the body sizes, proportions, and distributions of personnel in the Army population. Such information is obtained from anthropometric data. Anthropometry is the measurement of the human body, and the resulting measurements, collected during an anthropometric survey, represent the source of the body size information which is required.

New anthropometric data now are available for Army women, as well as workspace measurements and strength measurements. While there has been relatively little change in the body dimensions of Army women, comparisons of data for men and women clearly show that serious design and sizing problems will be encountered in the development of clothing and equipment intended for use by both Army men and women. [Abstract]

124 White, Robert M. UNITED STATES ARMY ANTHROPOMETRY: 1946-1977. Technical Report NATICK/TR-79/007, U.S. Army Natick Research and Development Command, Natick, MA, July 1978. 303 pages

KEY WORDS: Anthropometric Survey, Body Size, Comparative Anthropometry, Female Anthropometry, Gender Variation, Human Engineering, Male Anthropometry, Secular Trends, Summary Statistics

Body size information on both men and women of the U.S. Army is available in the form of data collected during several major anthropometric surveys carried out during the past 31 years. Anthropometric data for Army men and women measured in 1946, for Army men and male basic trainees measured in 1966, and for Army women and male basic trainees measured in 1977 are presented in this report.

Anthropometric data for these six series of U.S. Army personnel are presented in summary tables, in both centimeters and inches. Data for a total of 118 body measurements have been extracted from the summary tables and collated. Through the use of this format, all of the available anthropometric data for any one body measurement may be seen on two facing pages of statistical and percentile values, either in centimeters or in inches. Data for 14 workspace measurements of both Army men and women also are included.

Comparisons of body size between Army men of 1946 and 1966, between Army male basic trainees of 1966 and 1977, between Army women of 1946 and 1977, and between Army men of 1966 and Army women of 1977 are presented and discussed.

This summary of over 30 years of U.S. Army anthropometry indicates that there have not been any marked increases in the body size of U.S. Army personnel. A comparison of anthropometric data on Army men and women does indicate, however, that the differences in body size and proportions between men and women deserve serious consideration in the design and sizing of Army clothing and equipment intended for use by both men and women.

125 THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME V — U.S. CORRELATIONS. Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, September 1978.

KEY WORDS: Anthropometric Survey, Computer Tape, Correlation Coefficients, Female Anthropometry, Male Anthropometry, Pilots, U.S. Air Force

Correlation matrices based on data from USAF anthropometric surveys of women (1968, 127 variables), flying personnel (1950, 128 variables; 1967, 190 variables), and basic trainees (1965, 161 variables); a U.S. Army survey of women separatees (1946, 60 variables); the Health Examination Survey of civilian adults (1960-1962, 18 variables); and a survey of law enforcement officers (1974, 23 variables) are presented for use by engineers who need them in solving design problems and for anthropologists and statisticians whose analyses and understanding of the interrelationships of body size data depend significantly on these coefficients. Sample sizes in these surveys ranged from almost 2,000 upward. Sample means and standard deviations are presented for all variables involved. The contents of this tape are also described in the report, Intercorrelations of Anthropometric Measurements: A Source Book for USA Data (Ref. No. 141).

126 White, Robert M. ANTHROPOMETRY AND HUMAN ENGINEERING. Yearbook of Physical Anthropology, Vol. 21, 42-62, 1978. The American Association of Physical Anthropologists, Washington, DC

KEY WORDS: Anthropometry, Applied Physical Anthropology, Bibliography, Civilians, Human Engineering

Anthropometry has a long tradition as a recognized part of physical anthropology. Although there is a general lack of interest in anthropometry among many physical anthropologists today, anthropometric data have become widely utilized and applied in the field of human engineering, which is concerned with the integration and compatibility between people and all kinds of equipment. The need for anthropometric data for use in human engineering is constantly increasing and potential opportunities for the applications of anthropometry are expanding rapidly. The sources of anthropometric data on the U.S. military population and on the U.S. civilian population of adults and children are reviewed. Sources of anthropometric data from various foreign countries also are reviewed briefly. The literature on anthropometry and human engineering is discussed and an extensive bibliography of 105 references is provided.

- 127 White, Robert M. ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY.  
(Paper presented at the 22nd annual meeting, Human Factors Society, Detroit, MI, 19 October 1978). Proceedings of the Human Factors Society, 22nd Annual Meeting, Detroit, MI, October 16-19, 1978, 456-460.

**KEY WORDS:** Anthropometric Survey, Clothing Sizing, Female Anthropometry, Gender Variation

A new anthropometric survey of U.S. Army women was planned and carried out in 1976-1977 in response to the need for current and comprehensive body size data for the women who make up an increasingly large part of the United States Army. The main purpose of the survey was to obtain and develop statistical data on the body size and proportions of Army women.

During the survey, data for 69 basic body dimensions were obtained on a sample of 1,331 Army women, covering a wide range of age, rank, and military assignment. Additional data were collected on series of between 200 and 300 women for 28 other body measurements, 31 head and face measurements, 14 workspace measurements, and 9 static strength measurements. Many of the measurements made had not been previously reported for any large-scale survey of women, military or civilian. Other measurements were selected to supplement and complement data already available to provide up-to-date information for use in the design of clothing, protective equipment, workspace and industrial equipment which women in the Army wear, operate, or within which they work. Measurements were selected to update and increase the data already available for use in the design of clothing, protective equipment, workspace and industrial equipment all of which are used by Army women.

As a result, new anthropometric data now are available for Army women, as well as workspace measurements and strength measurements. While there has been relatively little change in the body dimensions of Army women between 1946 and 1977, comparisons of data for men and women clearly show that serious design and sizing problems will be encountered in the development of clothing and equipment intended for use by both Army men and women. [Abstract]

### 1979 PUBLICATIONS

- 128 White, Robert M. **THE ANTHROPOMETRY OF UNITED STATES ARMY MEN AND WOMEN: 1946-1977.** Human Factors, Vol. 21, No. 4, 473-482, August 1979.

**KEY WORDS:** Anthropometric Survey, Body Size, Comparative Anthropometry, Gender Variation, Secular Trends

A large amount of information on the body size of United States Army personnel, both men and women, has been collected during several anthropometric surveys carried out between 1946 and 1977. Changes in the body size of Army men between 1946 and 1966 and of Army women between 1946 and 1977 may be examined in an analysis of these anthropometric data. The data also may be utilized to define the contrasts in body size between Army men and women for application in the design and sizing of clothing and in the human engineering of equipment and materiel intended for use by both Army men and women.  
[Abstract]

### 1980 PUBLICATIONS

- 129 Tebbetts, Ilse O., Thomas Churchill, and John T. McConville. **ANTHROPOMETRY OF WOMEN OF THE U.S. ARMY — 1977; REPORT NO. 4, CORRELATION COEFFICIENTS.** Contract Report (Contract DAAK 60-79-C-0097), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-80/016, U.S. Army Natick Research and Development Command, Natick, MA, February 1980. 117 pages

**KEY WORDS:** Anthropometric Survey, Correlation Coefficients, Female Anthropometry, Regression Analysis, Summary Statistics

Correlation coefficients for the 161 variables measured in the 1976-77 anthropometric survey of U.S. Army women are given in this document, the fourth in a series of five reports describing the results of that study. Five sets of measurements were taken in the original survey; these included a core series, plus subsets of traditional, workspace, head-face, and static strength measurements. Correlations are given for all core measurements, for each of the subsets, and for combinations of each subset (except for the head-face group) with the core dimensions.

Intended as a self-sufficient guide to designers of military clothing, equipment, and workspaces, this report contains summary statistics for the five sets of measurements and height-weight regression equations to aid users in estimating given dimensions for groups or individuals for whom directly measured data do not exist. Also included here are instructions for creating regression equations from variables other than height and weight. Visual indexes for all the variables are presented for the benefit of users seeking to identify particular dimensions but who are not familiar with anthropometric terminology.

- 130 **THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME VI — THE 1946 SURVEY OF ARMY FEMALE SEPARATEES.** Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1980.

**KEY WORDS:** Anthropometric Survey, Computer Tape, Female Anthropometry

The 1946 Survey of Army Female Separatees was conducted at the end of World War II at the separation census on 3,614 nurses, 4,445 enlisted WAC's, and 484 WAC commissioned officers. Publications referring to this survey are: (1) Reference Anthropometry of Army Women (Ref. No. 10); (2) Applications of Anthropometry to the Determination of Size in Clothing (Ref. No. 4); and (3) Survey of

Body Size of Army Personnel, Male and Female: Phase 4, Body Dimensions of Army Females (Ref. No. 2). Punched cards containing the raw data were supplied to AFAMRL in 1972 by Robert M. White.

- 131 THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME VII -- THE 1966 SURVEY OF ARMY PERSONNEL. Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1980.

KEY WORDS: Anthropometric Survey, Computer Tape, Male Anthropometry

The 1966 Survey of Army Personnel was sponsored by the Defense Supply Agency and conducted in late 1965 and early 1966 by the U.S. Army Natick Laboratories, Natick, Massachusetts, and the U.S. Army General Test Activity. The survey was directed by Mr. Robert White of Natick Laboratories, and data editing and analysis were done by Edmund Churchill of the Anthropology Research Project, then at Antioch College, under contract to the Air Force. This survey is thoroughly documented in The Body Size of Soldiers: U.S. Army Anthropometry - 1966 (Ref. No. 111).

- 132 THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME VIII -- 1970 SURVEY OF ARMY AVIATORS. Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1980.

KEY WORDS: Anthropometric Survey, Aviators, Computer Tape, Male Anthropometry, Pilots

An anthropometric survey of U.S. Army Aviators was conducted at Fort Rucker, Alabama, in 1970. Data for 85 body measurements and for several variables describing the socio-military background of the survey subjects were gathered on a sample of 1,482 flight personnel.

The sample consisted of 388 enlisted men, 259 warrant officers, 410 rated pilots (warrant), 186 commissioned trainees, and 234 rated pilots (commissioned). Complete details and the results are published in Anthropometry of U.S. Army Aviators - 1970 (Ref. No. 112).

133 THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME IX — 1977 SURVEY OF U.S. ARMY WOMEN. Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1980.

KEY WORDS: Anthropometric Survey, Computer Tape, Female Anthropometry, Gender Variation, Male Anthropometry

The 1977 Survey of U.S. Army Women was conducted at four Army bases during the winter of 1976-1977. The survey was carried out and a series of reports prepared by the Anthropology Research Project under contract with the U.S. Army Natick Research and Development Command, Natick, Massachusetts. Data for 69 body size measurements were obtained on a sample of 1,331 women (Subject No. 92 has been deleted from this tape because of extreme obesity) who covered a wide range of age, rank, and military assignments. Additional data were obtained on four subgroups of between 200 and 300 women for (1) other standard body measurements, (2) workspace measurements, (3) head and face measurements, and (4) static strength measurements. A small sample of male subjects (287) were measured for an abbreviated set of measurements at the end of the female survey to provide comparative data. The results of this survey were published in Anthropometry of Women of the U.S. Army - 1977, Reports No. 1-5 (Ref. Nos. 120, 121, 122, 123, 131).

The tape is divided into ten files:

1. File No. 1 has index and background information.
2. File No. 2 has the core group of 69 measurements plus 10 background variables for 1330 subjects.
3. File No. 3 has 28 standard body size measurements measured on 255 subjects. Stature and weight from the core group of measurements have been included for each subject.
4. File No. 4 has 14 workspace measurements plus stature and weight from the core group of measurements for 300 subjects.
5. File No. 5 has 31 head and face measurements plus head circumference, head length, and head breadth from the core group of measurements for 216 subjects; ear length, ear breadth, and biauricular breadth were also measured on 37 subjects.
6. File No. 6 has 36 static strength measurements plus stature and weight from the core group of measurements for 349 subjects.
7. File No. 7 has 44 measurements from the core group and 14 measurements from the standard body size subgroup plus weight and background variables for 287 Army men.

8. File No. 8 has 14 workspace measurements plus stature and weight from the core group of measurements for 106 Army men.
9. File No. 9 has 34 head and face measurements plus head circumference, head length, and head breadth from the core group of measurements for 102 Army men.
10. File No. 10 has 36 static strength measurements plus stature and weight from the core group of measurements for 102 Army men.

134 THE AFAMRL ANTHROPOMETRIC DATA BANK LIBRARY: VOLUME X — U.S. ARMY CORRELATIONS. Computer Tape, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio, May 1980.

KEY WORDS: Anthropometric Survey, Aviators, Computer Tape, Correlation Coefficients, Female Anthropometry, Male Anthropometry

This data tape contains correlation coefficients for the surveys found in Volumes VI-IX. This tape is divided into nine files:

1. File 1: Table Contents
2. File 2: 1946 Army Female Separatees NV=65 NS=1791
3. File 3: 1966 Army Personnel NV=75 NS=6646
4. File 4: 1970 Army Aviators NV=88 NS=1482
5. File 5: 1977 Army Women—  
Core Anthropometry NV=70 NS=1330
6. File 6: 1977 Army Women—  
Core & Traditional Anthropometry  
NV=98 NS=255

7. File 7: 1977 Army Women--  
Core & Workspace NV=84 NS=296
8. File 8: 1977 Army Women--Head & Face  
NV=37 NS=215
9. File 9: 1977 Army Women--Core & Static Strength  
NV=88 NS=344

(NV = Number of Variables for that file and NS = Number of Subjects)

The surveys used in this volume are referenced in the following publications: Reference Anthropometry of Army Women (Ref. No. 10); Application of Anthropometry to the Determination of Size in Clothing (Ref. No. 4); Survey of Body Size of Army Personnel, Male and Female: Phase 4, Body Dimensions of Army Females (Ref. No. 2); The Body Size of Soldiers (Ref. No. 111); Anthropometry of U.S. Army Aviators--1970 (Ref. No. 112); Anthropometry of Women of the U.S. Army--1977 (Ref. Nos. 120-123, 131).

135 White, Robert M. SOURCES OF COMPARATIVE ANTHROPOMETRIC DATA.  
Paper prepared for presentation at a NATO Symposium on  
Anthropometry and Biomechanics: Theory and Application,  
Queen's College, Cambridge University, Cambridge, England,  
July 7-11, 1980.

KEY WORDS: Anthropometry, Comparative Anthropometry, Foreign  
Anthropometry, Geographical Variation, Racial  
Variation

Anthropometric data from various sources and from a variety of populations may be compared, since in 1980 we have a wealth of anthropometric data from many parts of the world. While there are still disturbing gaps in our anthropometric knowledge, it is possible to discuss comparative anthropometric data on a reasonably firm basis.

One principle, long advocated by ergonomists and anthropologists interested in the applications of anthropometric data, is that the data utilized should be those of the population for whom the results are intended, whether the problem at hand is human engineering or clothing. However, since the anthropometric data are not always immediately available for every single population of interest, we resort to comparisons. Such comparisons obviously show similarities in some instances, but in many cases differences are found not only in general body size but particularly in body proportions.

Major sources of comparative anthropometric data are discussed, such as the U.S. Air Force AFAMRL Data Bank, the newly-published NASA Anthropometric Source Book, and U.S. military publications (MIL-STD-1472, MIL-HDBK-759, and the DOD-HDBK-743). Comparative anthropometric data from various foreign populations also are discussed.

136 DEPARTMENT OF DEFENSE MILITARY HANDBOOK: ANTHROPOMETRY OF U.S. MILITARY PERSONNEL (METRIC). DOD-HDBK-743 (Metric), U.S. Government Printing Office, Washington, D.C., April 1991.

KEY WORDS: Anthropometric Survey, Anthropometry, Handbook, Summary Statistics

The purpose of this Handbook is to present body size information on United States military personnel in the form of anthropometric data for over 200 body measurements, including weight and age. Drawn from 15 surveys, these data are suitable for human factors engineering applications in the design and development of military systems, equipment, and materiel, and in the design and sizing of military clothing and personal equipment.

137 White, Robert M. COMPARATIVE ANTHROPOMETRY OF THE HAND.  
Technical Report NATICK/TR-81/010, U.S. Army Natick Research  
and Development Laboratories, Natick, MA, December 1980.  
186 pages

KEY WORDS: Bibliography, Bivariate Tables, Comparative  
Anthropometry, Foreign Anthropometry, Geographical  
Variation, Glove Sizing, Hand, Handwear,  
Tariff Derivation

Comparative anthropometric data on the human hand are presented and discussed in detail in this technical report. Since reliable and definitive data on the hands of the U.S. civilian population are lacking, anthropometric data on the hands of the U.S. military population of men and women may be utilized in analyses of handwear sizing.

Data are presented for ten hand measurements: Hand Length, Palm Length, Thumb Crotch Length, Hand Breadth, Hand Breadth at Thumb, Hand Circumference, Hand Circumference at Thumb, Fist Circumference, Wrist Circumference, and Hand Thickness. These hand measurements are defined and illustrated.

Detailed anthropometric data on the hands of U.S. Army men and women are presented in the form of bivariate tables which depict the distribution of various categories of hand sizes and show the interrelationships among hand dimensions.

Selected anthropometric data on the hands are also presented for a variety of foreign military populations in order to illustrate the range of variation in hand size to be found in different parts of the world.

In the final section, hands and handwear are examined in terms of sizing. A listing of standard U.S. Army handwear items is presented, and the problems of sizing in these types of handwear are discussed. The sizing of handwear is based primarily on the circumference of the hand. The unit of measurement used in the glove industry for the sizing of handwear is not the English inch, but the French or glover's inch, which is equivalent to 27.0 millimeters. The development of tariffs for handwear is explained, accompanied by illustrative examples showing tariffs of handwear for U.S. Army men, U.S. Army women, and a combined tariff for both U.S. Army men and women. The text is then concluded by an extensive bibliography.

### 1981 PUBLICATIONS

- 138 Churchill, Thomas, Kathleen M. Robinette, and Glen Potter. **SELECTED BIVARIATE FREQUENCY TABLES: U.S. ARMY MEN AND WOMEN.** Contract Report (Contract DAAK 60-79-C-0097), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-81/012, U.S. Army Natick Research and Development Laboratories, Natick, MA, January 1981. 209 pages

**KEY WORDS:** Bivariate Tables, Clothing Design, Female Anthropometry, Gender Variation, Male Anthropometry

Bivariate tables graphically portray the relationship between two dimensions and have traditionally played an important role in the use of anthropometric data by clothing and workspace designers. Published in this report, for the first time, is a set of bivariate tables in which men's and women's data are presented in comparable form, with the same units, the same interval widths, and the same interval endpoints. This presentation of the data will facilitate the use of the bivariate tables for design problems which involve both men and women. This particular set has been selected for the benefit of clothing designers in particular; however, many of them may be applicable to other types of design problems.

- 139 Robinette, Kathleen M., Thomas Churchill, and John T. McConville. **ANTHROPOMETRIC SIZING SYSTEMS FOR ARMY WOMEN'S FIELD CLOTHING.** Contract Report (Contract DAAK 60-79-C-0097), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-81/026, U.S. Army Natick Research and Development Laboratories, Natick, MA, March 1981. 231 pages

**KEY WORDS:** Bivariate Tables, Clothing Sizing, Female Anthropometry, Regression Analysis

This report contains a series of anthropometrically based sizing programs and tariffs for Army women's field clothing. Included here are sizing systems for upper body, lower body, and total body garments. Designed for use by clothing designers and pattern makers, this document consists in large part of sizing tables on which recommended values for some 59 dimensions relevant to garment construction are highlighted for easy identification. Regression equations, rather than more traditional methods, were used to develop the sizing data. This report also contains sufficient supportive material to permit designers to modify suggested dimensional values or to compute alternative sizing programs.

A visual index, accompanied by measurement descriptions, and bivariate distribution tables on which size categories have been graphically superimposed serve as visual references for users. A glossary of terms also is included.

Source of the dimensional data used in this report was a survey of 1,330 U.S. Army women conducted in 1976-1977.

- 140 Robinette, Kathleen M., Thomas Churchill, and Ilse O. Tebbetts. **INTEGRATED SIZE PROGRAMS FOR U.S. ARMY MEN AND WOMEN.** Contract Report (Contract DAAK 60-79-C-0097), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-81/032 U.S. Army Natick Research and Development Laboratories, Natick, MA, July 1981. 93 pages

**KEY WORDS:** Body Size, Clothing Sizing, Female Anthropometry, Gender Variation, Male Anthropometry, Sizing Systems

Appearing in this report for the first time are anthropometric sizing programs developed for Army field clothing to be worn by both men and women. Dimensional data were derived from a statistical analysis of body size data obtained from Army men and women, and take into account not only size differentials but the marked proportional differences which exist between the two sexes.

Formatted for use by clothing designers and patternmakers, the bulk of the report consists of sizing tables which include recommended design values for a total of 26 dimensions for each of 20 sizes. Two separate programs are given, one devised for upper body garments and one for lower body garments.

Although clothing designs based on these sizing programs have not, at this writing, been executed and field tested, these data are felt to be the most promising yet available to accommodate all Army personnel.

- 141 McConville, John T., Kathleen M. Robinette, and Robert M. White. **AN INVESTIGATION OF INTEGRATED SIZING FOR U.S. ARMY MEN AND WOMEN.** Contract Report (Contract DAAK 60-79-C-0097), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-81/033, U.S. Army Natick Research and Development Laboratories, Natick, MA, August 1981. 67 pages

**KEY WORDS:** Anthropometry, Clothing Sizing, Gender Variation, Sizing Systems

Described in this report is a step-by-step analysis of anthropometric sizing data leading to the development of integrated sizing programs for use in the design of field clothing for Army men and women.

Spurred by the need to clothe and equip increasing numbers of women for almost all of the Army's occupational specialties, and by the failure of scaled-down men's sizes to properly fit many women, this research was undertaken to identify the critical dimensional differences between men and women, and to devise single sizing systems which would take these variations into account.

Concepts underlying the development of anthropometric sizing systems, the problems unique to sizing for a mixed male/female population, and analytic procedures employed in seeking an effective sizing solution are all described here in some detail. Alternative sizing schemes, beginning with those based on traditional key dimensions, are examined and two 20-size programs — one each for upper- and lower- body garments — are recommended.

This report provides the theoretical basis for a proposed sizing system and is designed for persons interested in a general approach which may be applied to the solution of a wide range of integrated sizing problems likely to be encountered by the U.S. Army in providing clothing, equipment and workspaces for both men and women. A companion report (Integrated Size Programs for U.S. Army Men and Women) contains the actual sizing data in a format intended for use by designers and patternmakers.

## 1982 PUBLICATIONS

- 142 White, Robert M. **COMPARATIVE ANTHROPOMETRY OF THE FOOT.** Technical Report NATICK/TR-83/010, U.S. Army Natick Research and Development Laboratories, Natick, MA, December 1982. 320 pages

**KEY WORDS:** Bibliography, Bivariate Tables, Comparative Anthropometry, Female Anthropometry, Foot, Footwear, Foreign Anthropometry, Geographical Variation, Male Anthropometry, Tariff Derivation

Comparative anthropometric data on the human foot are presented and discussed in detail in this technical report. Since reliable and definitive data on the feet of the U.S. civilian population are lacking, anthropometric data on the feet of the U.S. military population of men and women may be utilized in analyses of footwear sizing.

Data are presented for fourteen foot measurements: Foot Length, Instep Length, Foot Breadth, Heel Breadth, Bimalleolar Breadth, Ball of Foot Circumference, Instep Circumference, Heel-Ankle Circumference, Lateral Malleolus Height, Medial Malleolus Height, Ankle Height, Ankle Circumference, Calf Height, and Calf Circumference. These foot measurements are defined and illustrated.

Detailed anthropometric data on the feet of U.S. Army men and women are presented in the form of bivariate tables which depict the distribution of various categories of foot sizes and show the interrelationships among foot dimensions.

Selected anthropometric data on feet also are presented for a variety of foreign military populations in order to illustrate the range of variation in foot size to be found in different parts of the world.

In the final section, feet and footwear are examined in terms of the sizing of footwear. A listing of standard U.S. Army footwear is presented, and the problems of sizing in these types of footwear are discussed. The development of tariffs for footwear is explained, with illustrative examples showing tariffs of footwear for U.S. Army men, for U.S. Army women, and a combined tariff for both U.S. Army men and women. The report then concludes with an extensive bibliography.

143 Churchill, Edmund. ROBERT MANSON WHITE, 1916-1981. American Journal of Physical Anthropology Vol. 59, 360, December 1982.

KEY WORDS: Biography, Obituary, White, Robert M.

Robert White was the senior physical anthropologist of the U.S. Army Natick Research and Development Center until his death in November 1981. This obituary includes biographical information and summarizes his research.

### 1984 PUBLICATIONS

- 144 Johnson, Richard F. **ANTHROPOMETRY OF THE CLOTHED U.S. ARMY GROUND TROOP AND COMBAT VEHICLE CREWMAN.** Technical Report NATICK/TR-84/034, U.S. Army Natick Research and Development Center, Natick, MA, July 1984. 102 pages

**KEY WORDS:** Chemical Protective Clothing, Clothed Anthropometry, Cold Weather Clothing, Combat Vehicles, Hot Weather Clothing, Human Engineering, Load Carrying Equipment, Male Anthropometry

In order to make estimates of the spatial allowances needed for the clothed and fully equipped crew and passengers of a ground combat vehicle, anthropometric data were collected on five nude male soldiers who approximated the percentile range of U.S. Army male soldiers and U.S. Army armor crewmen on height and weight. Anthropometric data were also collected on the same individuals when they were outfitted in each of four ground combat vehicle crewman's clothing ensembles and each of four ground troop clothing ensembles. The crewman's ensembles were for hot weather, hot weather with chemical protection, extreme cold weather, and extreme cold weather with chemical protection. The ground troop clothing ensembles were the same with the addition of load-carrying equipment. For each of 28 body dimensions, a difference score was calculated to reflect the changes in body size as a function of donning each clothing ensemble. Predicted measurements of the clothed body were then generated for each of the eight clothing ensembles.

### 1985 PUBLICATIONS

- 145 Gordon, Claire C. **ANTHROPOMETRY, ALLOMETRY, AND SEXUAL DIMORPHISM IN THE DESIGN OF PROTECTIVE CLOTHING AND EQUIPMENT.** (Paper presented at the 54th annual meeting of the American Association of Physical Anthropologists, Knoxville, TN, April 1985.) American Journal of Physical Anthropology, Vol. 56, No. 2, 176, February 1985.

**KEY WORDS:** Allometry, Anthropometry, Clothing Design, Correlation Coefficients, Gender Variation, Human Engineering

Research into the design and sizing of protective equipment such as helmets, respirators, gloves, and field clothing is rarely thought of as anthropological in scope. Nevertheless, optimizing the fit of protective equipment depends primarily on an understanding of the morphometric characteristics of the user population. The number of sizes needed is determined by the amount of variation present in body dimensions critical to fit and function. The selection of one or more size indicators (such as neck circumference and sleeve inseam for shirts) is determined by correlative relationships between the size indicators and other critical dimensions. Garment shape and the dimensional changes between sizes are determined by allometric relationships between the size indicator dimension(s) and other body dimensions critical to garment fit.

Naturally, such morphometric features vary among population samples of different ages, sexes, and races. In private industry, these differences are accommodated by catering to a particular subset of the market such as "juniors" or "tall men." Unlike the private sector, the Army must provide clothing and equipment for all body sizes and shapes in its user population. This paper discusses the ways in which research in anthropometry, allometry, and biomechanics has contributed to design and sizing solutions for morphometrically heterogeneous user groups.

[Abstract]

- 146 Bradtmiller, Bruce, Jyoti Ratnaparkhi, and Ilse O. Tebbetts.  
DEMOGRAPHIC AND ANTHROPOMETRIC ASSESSMENT OF U.S. ARMY  
ANTHROPOMETRIC DATA BASE. Contract Report (Contract  
DAAK60-84-C-0086), Anthropology Research Project, Inc., Yellow  
Springs, Ohio. Technical Report NATICK/TR-86/004, U.S. Army Natick  
Research, Development and Engineering Center, Natick, MA, August  
1985. 78 pages

KEY WORDS: Age Changes, Anthropometry, Demography, Gender Variation,  
Human Engineering, Racial Variation, Secular Trends, Stature,  
Weight

It has been nearly 20 years since the last anthropometric survey of Army males was conducted and about eight years since the last survey of Army females. The purpose of this report is to assess the extent to which the Army's existing anthropometric data base is representative of the current Army active duty force, both demographically and anthropometrically. The demographic variables of age, sex, and race are compared for the Army's existing anthropometric data base, the current active duty force, and the projected force of the 1990's. The changes in these variables occurring in the Army population are also contrasted with those occurring in the U.S. population at large. The anthropometric variables of stature and weight are compared for the existing data base and current active duty officers. Other anthropometric variables that are affected by race and age are also examined. Differences in anthropometric variables between the existing data base and the current active duty force are discussed in the context of secular trends in anthropometric measures from the U.S. population at large and other military populations. The implications of using the Army's personal equipment are examined in light of the present and projected demographic composition of the Army active duty force.

## 1986 PUBLICATIONS

- 147 Baumgartner, Richard N. **ASSOCIATIONS BETWEEN IMPEDANCE AND ANTHROPOMETRIC VARIABLES.** (Paper presented at the 55th annual meeting of the American Association of Physical Anthropologists, Albuquerque, NM, April 1986. Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA and by Grant HDAM-12252, National Institute of Health.) American Journal of Physical Anthropology Vol. 69, No. 2, 173-174, February 1986.

**KEY WORDS:** Bioelectric Impedance, Body Composition, Correlation Coefficients, Gender Variation, Lean Body Mass, Skinfold Measurements

The use of bioelectric impedance in measuring body composition is based on the assumption that lean tissue conducts a low frequency alternating electric current better than fat tissue. Theoretically, it should be possible to estimate the volume of lean body mass (LBM) from stature squared divided by impedance, if electrodes are placed at the wrist and ankle. However, the human body, due to its complex composition, is not a uniform conductor. Therefore, it is useful to know how impedance correlates with anthropometric variables such as weight, circumferences and skinfold thicknesses.

Impedance and anthropometric measurements, including stature, weight, arm and calf circumference, triceps, biceps, subscapular, midaxillary, paraumbilical, anterior thigh and lateral calf skinfolds, were made on 177 healthy White and Black adults of each sex, ranging in age from 18 to 30 years old. Correlations between impedance and anthropometric variables were calculated for subgroups defined by age, race and sex. Impedance was not correlated significantly with stature, but had significant negative correlations with weight, arm and calf circumferences, and estimated upper arm and calf muscle areas in each subgroup. It had a significant positive correlation with the sum of the skinfold measurements in women but not in men. Impedance had significant positive correlations with arm and leg skinfolds, but was not correlated with trunk skinfolds in men and women. The pattern of correlations suggests that impedance is affected by the relative amounts of muscle and fat in the extremities. In men the distribution of fat may be more important than overall "fatness" in determining impedance. [Abstract]

- 148 Chumlea, William Cameron. **THE INFLUENCE OF PHYSIOLOGIC AND PHARMACOLOGIC VARIABLES ON IMPEDANCE MEASURES.** (Paper presented at the 55th Annual Meeting of the American Association of Physical Anthropologists, Albuquerque, NM, April 1986. Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center and by Grant HDAM-12252, National Institute of Health.) American Journal of Physical Anthropology, Vol. 69, No. 2, 184, February 1986.

**KEY WORDS:** Bioelectric Impedance, Body Composition, Body Density, Body Fat, Diet, Exercise, Hydrostatic Weighing, Lean Body Mass, Menstrual Cycle, Skinfold Measurements

The study sample consisted of 78 White men, 19 to 27 years of age, and 75 White women, 18 to 30 years of age. Replicate measures of underwater weighing, stature, weight, midarm and calf circumferences and triceps, subscapular, biceps, midaxillary and lateral calf skinfolds together with measures of impedance were recorded from each participant by each of two observers working independently. Impedance was recorded with a Bioelectric Impedance Analyzer model 101. In addition, participants completed questionnaires regarding their previous 24 hour diet history, smoking and drinking habits, drug consumption and weekly physical activity levels.

In the men, there were no associations between levels of physical activity, interval from last drink or meal, and estimates of body composition from measures of body density, anthropometry or impedance. In the women, there were also no associations between interval from last drink or meal and corresponding estimates of body composition. However, those women who engaged in some form of regular exercise had larger estimates of body density and lean body mass and lower estimates of total and percent body fat than those women who did not exercise on a regular basis. This was true for estimates of body composition from measures of body density, anthropometry or impedance.

In the women, there were no associations among the interval from the first day of the last menstrual period, use of oral contraceptives and stature squared divided by impedance. [Abstract]

- 149 Guo, Shumei. THE USE OF IMPEDANCE IN THE ESTIMATION OF BODY COMPOSITION. (Paper presented at the 55th annual meeting of the American Association of Physical Anthropologists, Albuquerque, NM, April 1986. Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center and by Grant HDAM-12252, National Institute of Health.) American Journal of Physical Anthropology, Vol. 69, No. 2, 209, February 1986.

**KEY WORDS:** Bioelectric Impedance, Body Composition, Body Fat, Gender Variation, Hydrostatic Weighing, Lean Body Mass, Regression Analysis, Skinfold Measurements

Bioelectrical impedance was used to estimate measures of body composition (e.g., body density (BD); percent body fat (%BF); total body fat (TBF); lean body mass (LBM), obtained from underwater weighing, in a sample of 177 males and females with ages ranging from 18 to 30 years. The report centered on the effect of stature/impedance (S/I) in improving the accuracy of estimating body composition. Two sets of estimations for males and for females are presented. The first set involves two models which do not include skinfold measurements. One model used anthropometric variables as potential predictors, while the other made use of S/I in addition to anthropometric variables. The maximum R procedure for multiple regression analysis was employed to select the best predictive equations for various models. In the first model the equation was formulated in terms of stature, weight, and arm circumference and in the second model stature was replaced by S/I. The results showed that associated with the inclusion of S/I the multiple R values increased about 0.2 for BD and %BF, and about 0.13 for TBF and LBM, while the root mean squared errors (r.m.s.e.) decreased approximately 0.02 gm/cc for BD, 1% for %BF, and 0.8 kg for TBF and for LBM.

The second set of estimations is similar to the first except that the skinfold measurements were included. As expected, multiple R values increased and the r.m.s.e. decreased. These findings showed that impedance contributed to the estimation of body composition. Although the second set provided larger R values and smaller r.m.s.e., the contribution of impedance was less than in the first set.

- 150 Roche, Alex F. THE NEED FOR IMPROVEMENTS IN THE MEASUREMENT OF BODY COMPOSITION: SOME CRITICAL ISSUES. (Paper presented at the 55th annual meeting of the American Association of Physical Anthropologists, Albuquerque, NM, April 1986. Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center and by Grant HDAM-12252, National Institute of Health.) American Journal of Physical Anthropology, Vol. 69, No. 2, 256-257, February 1986.

**KEY WORDS:** Body Composition, Body Density, Body Fat, Hydrostatic Weighing, Lean Body Mass

Body composition (BC) can be measured in the living using "direct" or "indirect" methods. With the common "direct" methods, body density (BD) is measured by hydrostatic weighing, total body water (TBW) by isotopic dilution, total body potassium (TBK) from gamma radiation and total body calcium (TBCa) and total body nitrogen (TBN) by neutron activation. With hydrostatic weighing, almost all the error is associated with residual volume, but BD is affected by air in the gut which cannot be estimated reliably. Water exchange after the isotope was taken and exchange between the isotope and non-aqueous hydrogen may affect TBW values. Measures of TBK, TBCa and TBN are influenced by body geometry. The rather small errors of measurement of the direct measures (1.0-1.5%) show they are acceptable measures of what they attempt to measure. Unfortunately, considerable errors are introduced when these measures are used to estimate BC variables in all except young men. These estimates are of percent body fat (from BD), lean body mass (from TBW, TBK), total body protein (from TBN) and skeletal mass (from TBCa). For example, the estimation of percent body fat from hydrostatic weighing assumes a fixed specific gravity for triglycerides and for lean body mass. The second assumption is not justified.

The indirect methods include anthropometry, absorptiometry and bioelectric procedures. With each there are errors when the measured values are used to estimate BC. These critical issues must be addressed before further progress can be made.

- 151 Siervogel, Roger M. and Barbara Woynarowska. ASSOCIATIONS BETWEEN IMPEDANCE MEASURES OF BODY COMPOSITION AND BLOOD PRESSURE. (Paper presented at the 55th annual meeting of the American Association of Physical Anthropologists, Albuquerque, NM, April 1986. Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center and by Grant HDAM-12252, National Institute of Health.) American Journal of Physical Anthropology, Vol. 69, No. 2, 264-265, February 1986.

**KEY WORDS:** Bioelectric Impedance, Blood Pressure, Body Composition, Body Fat, Correlation Coefficients, Gender Variation, Hydrostatic Weighing, Lean Body Mass

In a study of body composition, 177 males and females aged 18 to 30 years were measured using hydrostatic weighing (HW) and bioelectrical impedance (I). An unselected subset of 110 of these individuals also had systolic (SBP) and 5th phase diastolic (DBP) blood pressure measured.

In an earlier HW study, significant positive partial correlations ( $r=0.2$  to  $0.3$ ) between measures of blood pressure (BP) and percent body fat (%BF-HW) and total body fat (TBF-HW) were observed in 217 adults aged 18 to 49 years, after adjusting for age (Siervogel et al., Hypertension 4: 382-386, 1982). A significant BP correlation with lean body mass (LBM-HW) was not found in that study.

Preliminary results from the current study are given in the following table of Pearson correlations between BP and body composition measures which were significantly different from zero at the 0.05 level. For both males and females, SBP was positively correlated with LBM estimated from impedance (LBM-I). In males, TBF and TBF estimated from impedance (TBF-I) were highly correlated with SBP; however, this is not true in females.

		LBM-HW	TBF-HW	LBM-I	TBF-I	S /I
Males (N=68)	SBP	0.24	0.34	0.29	0.37	--
	DBP	--	--	--	--	--
Females (N=52)	SBP	--	--	0.35	--	0.34
	DBP	0.30	--	--	--	--

These results indicate that impedance measures of body composition may be very useful in epidemiological studies of cardiovascular risk factors in which hydrostatic weighing would be impractical.

- 152 Gordon, Claire C. **ANTHROPOMETRIC SIZING AND FIT TESTING OF A SINGLE BATTLEDRESS UNIFORM FOR U.S. ARMY MEN AND WOMEN.** In: *Performance of Protective Clothing*, ASTM STP 900, R.L. Barker and G.C. Coletta (editors). American Society for Testing and Materials, Philadelphia, PA, 1986, 581-592.

**KEY WORDS:** Clothing Design, Clothing Sizing, Gender Variation, Key Dimensions, Regression Analysis, Tariff Derivation

Women in the U.S. Army currently wear field uniforms that were designed and sized for men. Downsizing the male patterns to fit women has accentuated the fitting problems caused by sexually dimorphic body proportions. Thus, female body dimensions must be considered in the design and sizing of Army field clothing. The integrated sizing system for men and women presented here was derived mathematically from the U.S. Army's anthropometric data base. Key sizing dimensions were established by selecting those variable pairs which minimize within-size variations of other body dimensions important to garment design. Design values for additional body dimensions critical to garment fit were calculated from regression equations that used the key sizing variables to predict the dimensions of the largest individual who will wear each size. Appropriate ease was added to these nude body dimensions to arrive at an empirically defined grading system. Fitting trials will test the hypothesis that this anthropometric sizing program can provide an adequate fit for both Army men and women.

- 153 Clauser, Charles E., John T. McConville, Claire C. Gordon, and Ilse O. Tebbetts. **SELECTION OF DIMENSIONS FOR AN ANTHROPOMETRIC DATA BASE, VOLUME I: RATIONALE, SUMMARY, AND CONCLUSIONS.** Contract Report (Contract DAAK60-84-C-0086), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-86/053, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, May 1986. 64 pages

**KEY WORDS:** Anthropometric Survey, Anthropometry, Body Size, Human Engineering, Measurement Techniques

A large number of body size variables were examined and rated for their usefulness in an anthropometric data base designed to serve present and future needs of the U.S. Army. These dimensions are assembled in groups representing various uses to which the Army might put these data, ranging from the design of clothing, personal protective equipment, and workspaces, to the development of link systems and human analogues. A total of 362 dimensions analyzed in this study were rated as marginal, useful or essential to one or more of these applications. Some 194 dimensions are suggested as candidates for measurement in a proposed new large-scale multipurpose survey of Army personnel.

Sources for the study included 34 anthropometric surveys of U.S. and foreign military and civilian subjects, as well as questionnaire surveys and interviews with clothiers, modelers, design engineers, physical anthropologists, and others experienced in the application of anthropometric data to military design problems. Dimension lists from fourteen large-scale surveys were selected for detailed review. Descriptions and analyses of all the dimensions measured in those surveys appear in Volume II of this report.

- 154 Clauser, Charles E., John T. McConville, Claire C. Gordon, and Ilse O. Tebbetts. SELECTION OF DIMENSIONS FOR AN ANTHROPOMETRIC DATA BASE, VOLUME II: DIMENSION EVALUATION SHEETS. Contract Report (Contract DAAK60-84-C-0086), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-86/054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, May 1986. 420 pages

**KEY WORDS:** Anthropometric Survey, Anthropometry, Human Engineering, Measurement Definitions, Measurement Techniques

Anthropometric dimensions measured in 14 major foreign and domestic military and civilian surveys were reviewed in detail for possible inclusion in an anthropometric survey of U.S. Army men and women. Detailed review of each dimension included the following information: a description of the dimension, subject position, and landmarks required; type of instrument used; significant technique differences among different surveys; alternative dimensions that could serve the same function in a data base; summary statistics from surveys that included the dimensions; notation of significant gender or racial differences for the dimension; ease of reproducibility, and factors contributing to reproducibility problems (if any); and a rating (with rationale) of the dimension's relative utility for a U.S. Army data base. Review sheets summarizing this information comprise Volume II of this report. Background information, discussion, and conclusions regarding those dimensions worthy of further consideration for inclusion in a U.S. Army anthropometric data base are presented in Volume I.

- 155 Roche, Alex F., William Cameron Chumlea, and Shumei Guo.  
**IDENTIFICATION AND VALIDATION OF NEW ANTHROPOMETRIC TECHNIQUES FOR  
QUANTIFYING BODY COMPOSITION.** Contract Report (Contract  
DAAK60-84-C-0054), Division of Human Biology, Department of  
Pediatrics, Wright State University School of Medicine, Yellow  
Springs, Ohio. Technical Report NATICK/TR-86/058, U.S. Army Natick  
Research, Development and Engineering Center, Natick, MA, October  
1986. 232 pages

**KEY WORDS:** Anthropometric Survey, Bioelectric Impedance, Body  
Composition, Body Density, Body Fat, Diet, Diurnal Variation,  
Exercise, Hydrostatic Weighing, Menstrual Cycle, Regression  
Analysis, Skinfold Measurements, Ultrasound

This study validates estimates of body composition from bioelectrical impedance (RJL Model BIA-101) against corresponding estimates of body composition from densitometry in a sample of 177 young men and women, of whom 14 percent were Black. Also, comparisons are made between measures of subcutaneous adipose tissue thickness using a portable ultrasound machine (EchoScan 1502) and Lange skinfold calipers in the same sample. In separate samples, measures of machine reliability were conducted between pairs of impedance machines and between ultrasound machines. In addition, tests were made of the possible effects of "physiological noise factors" on measures of impedance.

Bioelectric impedance is highly reliable as are measures of subcutaneous adipose tissue with Lange skinfold calipers. Ultrasonic measures of subcutaneous adipose tissue are not reliable and do not improve predictions of body composition over that of corresponding skinfold measurements.

Bioelectric impedance is not affected by physiological factors such as diet, time of day, exercise or the menstrual cycle. However, in those women who do not participate in some form of regular exercise, predictions of body composition from  $\text{Stature}^2/\text{Resistance}$  plus anthropometry do differ significantly from those of women who do exercise regularly. The addition of bioelectric impedance does improve the predictions of body composition from anthropometry alone compared to corresponding estimates from densitometry.

The use of the RJL model BIA-101 bioelectric impedance machine to measure body composition is recommended, with reservations, but the measurement of subcutaneous adipose tissue with the EchoScan 1502 portable ultrasound machine is not recommended.

### 1987 PUBLICATIONS

- 156 Bense, Carolyn K. and Claire C. Gordon. **AN INVESTIGATION OF THE FIT OF ARMY COMBAT BOOTS ON FEMALE SOLDIERS AND THE INFLUENCE OF THEIR FOOT/LEG DIMENSIONS ON FIT OUTCOME.** (Paper presented at the American Society for Testing and Materials conference, Cincinnati, OH, April 1987.)

**KEY WORDS:** Combat Boot, Fit Test, Foot, Footwear, Gender Variation, Lasts

Fit-testing of an expanded sizing system for the Army's new combat boot was conducted on 574 women and 293 men at Ft. Jackson, SC, in 1985. The boots were manufactured over the MIL-5 last and all of the 11 sizes of boots in the standard MIL-5 system were provided. These sizes range from 3 through 14, in five widths. Another 22 sizes ranging from 3 through 8 were made available in two additional widths which were intermediate between the standard widths. The primary purpose of the test was to determine whether the MIL-5 system with added widths could accommodate female soldiers. Data collected on each subject during the test included 31 foot and lower leg dimensions, commercial shoe sizes, foot injury history, and the predicted and best-fitting boot sizes.

Test results indicate that over 99 percent of the men and 99 percent of the women were able to be fit in the expanded MIL-5 system, whereas 96 percent of the men and 74 percent of the women were able to be fit in the standard MIL-5 system. Thus the added widths significantly improved the rate of successful fit, and the modified system should meet the Army's requirement to accommodate the 5th through 95th percentile soldier.

Quantitative analyses of the fit-test data have focused on identifying those foot dimensions most closely related to fitting success and failure. Relationships between foot dimensions, MIL-5 last dimensions, and fitting characteristics of the boot have been examined. In addition, statistical matching procedures have been employed in order to generate pairs of successfully/not successfully fit female subjects with similar key sizing dimensions (Ball of Foot Length, + 2mm; Ball of Foot Breadth, + 5mm). These matched samples have been analyzed for anthropometric differences in other foot dimensions that may have contributed to differences in fitting outcome.

This paper summarizes the results of the fit-test and subsequent data analyses. The results will be discussed in terms of military and commercial sizing systems for field boots.

- 157 Parham, Kenneth R., Carolyn K. Bense, and Claire C. Gordon.  
**ANTHROPOMETRIC VARIATION OF THE FOOT AMONG MALE AND FEMALE  
AMERICAN BLACKS AND WHITES.** (Paper presented at the American  
Society for Testing and Materials conference, Cincinnati, OH, April  
1987.)

**KEY WORDS:** Anthropometric Survey, Discriminant Analysis, Factor Analysis,  
Foot, Footwear, Gender Variation, Racial Variation

During the summer of 1985, anthropometric data of the foot and lower leg were collected on 867 male and female soldiers from Fort Jackson, South Carolina. The foot dimensions consist of 24 measurements on the right foot and five more from the left foot. With few exceptions, this data set represents one of the most comprehensive arrays of foot dimensions ever acquired on civilian or military personnel, especially females. Additionally, American Blacks and Whites of both genders are well-represented in the total sample. Thus, this data set provides a unique opportunity to utilize quantitative statistical analyses for exploring the nature of anthropometric variation of the human foot among Black and White males and females.

For analytical purposes, the Black subsample was restricted to those individuals who responded to questions of race and ethnicity on a biographical questionnaire with "Black" and "American of African Descent." This included 71 males and 230 females. The White subsample of 151 males and 226 females included those individuals who responded on the questionnaire with "White" and "American of European Descent."

Statistical analyses were performed only on the 24 measurements of the right foot. These data first were subjected to factor analysis in order to reduce redundancy in the anthropometric variables. Eight orthogonal factors were derived, comprising approximately 90 percent of the total variation. Factor scores were produced for each individual and these data were then subjected to discriminant analysis to assess differences between gender and race-specific groups. Differences among the groups are explained with reference to the derived factors.

The findings revealed in this study should help answer questions pertaining to anthropometric variation of the foot among genders and between racial groups. As such, this information should be of profound interest to designers and manufacturers of footwear.

- 158 Parham, Kenneth R., Claire C. Gordon, and Carolyn K. Benschel. **GENDER AND RACE DIFFERENCES IN FOOT DIMENSIONS.** (Paper presented at the 56th annual meeting of the American Association of Physical Anthropologists, New York, NY, April 1987.) American Journal of Physical Anthropology, Vol. 72, No. 2, 240-241, February 1987.

**KEY WORDS:** Anthropometric Survey, Discriminant Analysis, Factor Analysis, Foot, Gender Variation, Racial Variation

This study presents a multivariate analysis of 24 foot measurements obtained on male and female American Black and White soldiers from Fort Jackson, South Carolina. The Black samples consist of 71 males and 230 females. The white samples are comprised of 151 males and 226 females.

To reduce redundancy in the data, the 24 variables were factor analyzed before groups were compared for differences. Eight components comprising 90 percent of the total variation were subjected to varimax rotation. Factor scores were generated for each individual and these data were subjected to discriminant analysis to assess differences between gender- and race-specific groups.

Factor 1 (62 percent of variation) emphasizes foot length. Factor 2 (11 percent of variation) stresses foot breadth. Factors 3-6 collectively comprise 13 percent of the variation and emphasize foot height in specific regions of the foot. Factor 7 (2 percent of variation) emphasizes ankle circumference while Factor 8 stresses heel breadth. The 4-group discriminant analysis on the factor scores yielded two significant canonical functions. The first (60 percent of variation) loads most heavily on Factors 1 and 2, and effectively separates males and females. The second function (39 percent of variation) emphasizes Factor 3 (foot height in the arch and ankle regions) and separates Blacks and Whites. Based on these two functions, approximately 79 percent of all individuals were correctly classified into their respective gender- and race-specific groups. Tests for differences between centroids are significant for all pairs. Of particular interest is that the centroids for Black males and females are considerably closer to one another than are those for White males and females, suggesting that Whites are more sexually dimorphic in their foot dimensions than are Blacks.

- 159 Baumgartner, Richard N., William Cameron Chumlea, and Alex F. Roche. **ASSOCIATIONS BETWEEN BIOELECTRIC IMPEDANCE AND ANTHROPOMETRIC VARIABLES.** (Supported in part by Contract DAAK-60-C-0054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA) Human Biology, Vol. 59, No. 2, 235-244, April 1987.

**KEY WORDS:** Anthropometric Survey, Bioelectric Impedance, Body Composition, Body Fat, Correlation Coefficients, Regression Analysis, Skinfold Measurements

Associations of bioelectric resistance with anthropometric parameters for stature, weight, upper arm and calf circumferences, and seven skinfold thicknesses were analyzed in 153 young, White men and women. Bivariate correlations of resistance with weight and upper arm and calf circumferences were negative and statistically significant in each sex. There were small, but significant, negative correlations between resistance and subscapular and midaxillary skinfold thicknesses in women. Stepwise maximum R regressions demonstrated that 72 percent and 75 percent of the variance in resistance in men and women, respectively, were predicted by stature, weight (in women only), upper arm and calf circumferences, and mean skinfold thickness. Standard errors of prediction were approximately 5.5 percent (25 ohms) in men, and 5.9 percent (34 ohms) in women. An index of adipose tissue distribution, log(subscapular/lateral calf) skinfold thicknesses, was not associated with resistance in either sex.

- 160 Chumlea, William Cameron, Alex F. Roche, Shumei Guo, and Barbara Woynarowska. **THE INFLUENCE OF PHYSIOLOGIC VARIABLES AND ORAL CONTRACEPTIVES ON BIOELECTRIC IMPEDANCE.** (Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA) Human Biology, Vol. 59, No. 2, 257-269, April 1987.

**KEY WORDS:** Bioelectric Impedance, Body Composition, Diet, Diurnal Variation, Exercise, Menstrual Cycle, Oral Contraceptives

In the present study, three groups of young adults (N=4, N=153, N=29) were used separately or together to test for the effects of diurnal variation of diet or physical activity on bioelectric impedance and of the possible changes in bioelectric impedance during the menstrual cycle in women taking oral contraceptives and in women not taking oral contraceptives. In young adults of normal stature and weight, there was no significant association between measures of bioelectric resistance and time-of-day or between interval from previous meal or drink and means of the differences of body composition variables estimated from underwater weighing less corresponding values predicted from sex-specific equations using bioelectric resistance and anthropometry. In the women who did not participate in some form of regular physical activity, the means of the

differences of body composition variables estimated from underwater weighing less corresponding values predicted from bioelectric resistance and anthropometry were significantly different from corresponding mean differences for women who did participate in some form of regular physical activity. The corresponding findings in the men were not significant. Also, the effects of oral contraceptive usage, and of the timing within the menstrual cycle on measures of bioelectric resistance were not significant. Except for the effect of the absence of exercise in the women, the effects of the physiologic variables and oral contraceptive usage upon bioelectric impedance were not significant.

- 161 Guo, Shumei, Alex F. Roche, William Cameron Chumlea, Daniel S. Miles, and Roberta L. Pohlman. **BODY COMPOSITION PREDICTIONS FROM BIOELECTRIC IMPEDANCE.** (Supported in part by Contract DAAK-60-C-0054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA) *Human Biology*, Vol. 59, No. 2, 221-233, April 1987.

**KEY WORDS:** Bioelectric Impedance, Body Composition, Body Fat, Gender Variation, Regression Analysis

The prediction of body composition variables from bioelectric impedance (BI) has considerable potential for use in surveys, because BI is reliable, and the equipment is portable (weight, 1.04 kg). The purpose of the present study was to determine if BI with selected anthropometric variables predicted percent body fat (%BF) accurately. Two groups of subjects were used from whom accurate anthropometric variables were obtained. The validation group of 148 healthy White adults (77 men and 71 women) aged 18 to 30 was used to formulate two parsimonious models for each sex to predict %BF from selected anthropometric variables, one without and one with stature divided by resistance (S/R). The cross-validation group, aged 18 to 30 years (19 White men and 29 White women), was used to assess the stability of equations derived from S/R and anthropometric variables. Principal component analysis applied to 16 potential predictors showed five components explained most of the variation in %BF. All possible subsets of regression procedure was employed to select the best equation on the basis of: (1) five predictors at most, (2) minimum root mean square error and (3) 0.1 level of significance. The multiple R and r.m.s.e. were not changed by the inclusion of S/R in men. However, the inclusion of S/R changed the R from 0.73 to 0.81 and the r.m.s.e. from 3.83 percent to 3.22 percent in women. Cross-validation of the equations that included S/R showed the accuracy of prediction (coefficient of variation, 0.23 for men; 0.16 for women) was approximately the same as for the validation group. These findings indicated that the addition of S/R to selected anthropometric variables significantly improved the prediction of %BF for women, but not for men. [Abstract]

162 Siervogel, R.M., Barbara Woynarowska, William Cameron Chumlea, Shumei Guo, and Alex F. Roche. BIOELECTRIC IMPEDANCE MEASURES OF BODY COMPOSITION: THEIR RELATIONSHIP WITH LEVEL OF BLOOD PRESSURE IN YOUNG ADULTS. (Supported in part by Contract DAAK-6084-C-0054, U.S. Army Natick Research, Development and Engineering Center, Natick, MA) Human Biology, Vol. 59, No. 2, 245-255, April 1987.

KEY WORDS: Bioelectric Impedance, Blood Pressure, Body Composition, Body Fat, Correlation Coefficients, Gender Variation, Hydrostatic Weighing, Weight

There is evidence that increased body weight in adults is predominantly due to an increase in the amount of fat. The association of blood pressure with body weight could be due to the increased total body mass or to some underlying relationship between blood pressure and body fat. The separate influences of body size and fatness on level of blood pressure in adults was investigated in a sample of 62 men and 51 women aged 18 to 30 years. Total body fatness, percent body fatness and fat-free mass were estimated using hydrostatic weighing and from equations using anthropometry in combination with measures of bioelectrical impedance. Previous work in adults aged 18 to 49 years showed in both men and women a consistent positive correlation between level of systolic blood pressure and total body fat or percent body fat and no significant relationship to fat-free mass. Women, but not men, showed a similar relationship for diastolic blood pressure. In the present study, the results were less consistent. For diastolic blood pressure there were no significant relationships observed with any of the measures of body composition. For systolic blood pressure in men, findings were similar to those of the previous study for percent body fat and for total body fat. In the women, the relationships between fatness variables and blood pressure were not significant. However, contrary to the results of the previous study, a significant positive correlation was observed between fat-free mass and systolic blood pressure in both the men and the women. Components of body composition estimated from anthropometry in combination with bioelectric impedance are useful in epidemiological studies where underwater weighing is impractical.

- 163 Zehner, Gregory, Vance Deason, Cay Ervin, and Claire C. Gordon. A PHOTOGRAPHIC DEVICE FOR THE COLLECTION OF ANTHROPOMETRIC DATA ON THE HAND. Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-87/044, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, August 1987. 94 pages.

**KEY WORDS:** Hand, Hand Photobox, Measurement Techniques

A photographic device used to collect anthropometric data of the hand is described in this report. The hand photometric system, or photobox, was designed for measuring the human right hand, and evaluated for possible use in a large-scale Army anthropometric survey. The advantages of such a system are that it would be much faster than current methods of collecting hand data and would provide a permanent record from which measurements can be taken as needed.

Using the photobox, 16 hand measurements from 30 subjects were taken and compared to a more traditional method of collecting data. In this comparative method, finger breadths were measured by sliding calipers, while hand length, hand breadth, digit length, and crotch heights were measured from paper graphs on which landmark locations had been marked. This paper method was developed as a means of measuring hand records comparable to photobox silhouettes. Univariate statistics indicated that the results of the methods were very similar; differences between means of silhouette measurements and paper/caliper measurements ranged from 0.04 to 0.16 cm. Many of the larger differences were in finger breadths -- the caliper consistently produced smaller results due to skin compression.

The repeatability of the methods was found to be very high. Though the photobox method produced consistently greater intertrial differences -- due to inexact hand alignment procedures and silhouette measuring techniques -- the differences were very small (0.2 mm to 0.3 mm). Several recommendations for improving repeatability are suggested.

The authors conclude that the photobox is an excellent alternative to other methods. [Abstract]

## 1988 PUBLICATIONS

- 164 Gordon, Claire C. and Bruce Bradtmiller. **INTEROBSERVER ERROR IN A LARGE-SCALE ANTHROPOMETRIC SURVEY.** (Paper presented at the 57th Annual Meeting of the American Association of Physical Anthropologists, Kansas City, KS, March 24-26 1988). American Journal of Physical Anthropology, N.A. Vol. 75, No. 2, 215-216, February 1988 [Abstract].

**KEY WORDS:** Anthropometric Survey, Measurement Techniques, Observer Error

The adverse effects of interobserver error on morphometric population comparisons are well documented in the literature (Utermohle and Zegura, 1982). While interobserver error can rarely be avoided, it can be minimized by having a single individual locate and mark relevant landmarks, by limiting the number of observers for each variable, and by reviewing repeatability data daily to catch and correct measurer drift during data collection.

In this study, two pairs of "experts" participated in interobserver error trials designed to pre-set observer error limits for use in quality control of a large scale anthropometric survey. Each trial consisted of measuring 10 subjects twice; each pair participated in two trials. Mean interobserver differences were calculated over 10 subjects for each of the four trials, and varied between 0.5 mm (head breadth) and 15 mm (chest circumference). Error magnitude varied significantly as a function of dimensional magnitude, instrument used, and complexity of subject position.

Repeatability data were also collected twice daily in the field and reviewed with the measurers. Mean interobserver errors actually obtained in the field are significantly lower than those achieved by the "experts." These results suggest that establishment of permissible interobserver error in advance of data collection and frequent review of repeated measures during data collection can reduce interobserver error magnitude below those reported for experts measuring in a laboratory setting.

In addition, the magnitudes of error reported in these studies have proven particularly useful in evaluating the biological relevance of statistically significant differences which are, however, of relatively small magnitude. [Abstract]

- 165 Clauser, Charles E., Ilse O. Tebbetts, Bruce Bradtmiller, John T. McConville, and Claire C. Gordon. **MEASURER'S HANDBOOK: U.S. ARMY ANTHROPOMETRIC SURVEY, 1987-1988.** Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-88/043, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, May 4, 1988. 334 pages.

**KEY WORDS:** Anthropometric Survey, Female Anthropometry, Hand, Hand Photobox, Handbook, Head, Headboard, Male Anthropometry, Measurement Definitions, Measurement Techniques

The purpose of this manual is to describe and explain the tools and procedures required for the precise and accurate measurement of U.S. Army men and women. The handbook contains instructions for the measurement of 132 directly measured dimensions of the body, and for obtaining additional head and hand data collected with the use of two pieces of custom-designed equipment: an electronic headboard and a hand photometric system. Also included in this generously illustrated measurer's guide are instructions for locating and drawing the landmarks required to define and standardize the dimensions, suggestions for handling subjects, and a guide to the operations and care of the personal computers to be used to record and edit the data in the field. The measurements obtained in this anthropometric survey will form the bases for ensuring that Army clothing, equipment, and systems properly accommodate Army personnel who run the body-size gamut from small women to large men. [Abstract]

- 166 Churchill, Thomas D., Bruce Bradtmiller, and Claire C. Gordon. **COMPUTER SOFTWARE USED IN U.S. ARMY ANTHROPOMETRIC SURVEY 1987-1988.** Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-88/045, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, June 1988. 117 pages.

**KEY WORDS:** Anthropometric Survey, Data Editing, Data Entry, Hardware, Measurement Error, Measurement Techniques, Software

This report describes the hardware and software used in the 1987-1988 anthropometric survey of the U.S. Army. It includes a background section outlining how anthropometric data can be edited mathematically, and how such editing has been done in surveys of the past. It then describes the data entry and editing software which was created especially for the 1987-1988 survey, and how that software is based on historically proven techniques. Programs which randomly select subjects for measurement from among those who are screened and which calculate interobserver measurement error are also described. The appendices include a self-contained hardware/software user's guide, and complete program listings for all software used in the survey. [Abstract]

- 167 Annis, James F. and Claire C. Gordon. **THE DEVELOPMENT AND VALIDATION OF AN AUTOMATED HEADBOARD DEVICE FOR MEASUREMENT OF THREE-DIMENSIONAL COORDINATES OF THE HEAD AND FACE.** Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-88/048, U.S. Army Natick Research, Development & Engineering Center, Natick, MA, June 1988. 200 pages.

**KEY WORDS:** Anthropometric Survey, Automated Headboard Device, Face, Head, Head Measuring Device, Headboard, Observer Error

This report describes the development of an automated headboard device (AHD) for measuring three-dimensional coordinates of landmark locations on the head and face. Designed to be operated in conjunction with a portable computer which contains special software, the AHD produces on-line measurements which are compatible with the existing headboard data base (heights and depths), yet expands the information to include breadths. The device was developed for use in the 1987-1988 anthropometric survey of Army personnel. In its first field application, the AHD was programmed to measure 26 head and face landmarks selected on the basis of their usefulness in the design and construction of helmets, respirators, goggles, and other personal protective equipment.

A series of validation tests demonstrated that: (1) the AHD provides 3-D coordinates at nearly twice the speed as similar data obtained by traditional methods, (2) both intra- and interobserver error obtained with the AHD are less than those obtained with the traditional technique, and (3) the ability of operators to duplicate coordinate values of other operators nearly as well as they were able to duplicate their own, appeared to confirm the reliability of the device in the hands of different operators.

Included in this liberally illustrated report are detailed descriptions of how the AHD is designed and how it functions. A number of appendices provide drawings of component layouts, parts lists, software, and a user's manual. [Abstract]

- 168 Gordon, Claire C., William C. Chumlea, and Alex F. Roche. **STATURE, RECUMBENT LENGTH, AND WEIGHT.** In Anthropometric Standardization Reference Manual, T.B. Lohman, A.F. Roche, and R. Martorell (editors), Champaign, IL: Human Kinetics Books, 1988. 581-592.

**KEY WORDS:** Measurement Techniques, Recumbent Length, Stature, Weight

Stature is a major indicator of general body size and of bone length. When stature cannot be measured, recumbent length can be substituted. Weight is the most commonly recorded anthropometric variable. This chapter discusses recommended techniques, purpose, literature, and reliability for each of these dimensions.

- 169 Wilmore, Jack H., Roberto A. Frisancho, Claire C. Gordon, John H. Himes, Alan D. Martin, Reynaldo Martorell, and Vernon D. Seefeldt. **BODY BREADTH EQUIPMENT AND MEASUREMENT TECHNIQUES.** 17 Anthropometric Standardization Reference Manual, T.B. Lohman, A.F. Roche, and R. Martorell (editors), Champaign, IL: Human Kinetics Books, 1988. 27-38.

**KEY WORDS:** Ankle Breadth, Biacromial Breadth, Bi-iliac Breadth, Bitrochanteric Breadth, Chest Breadth, Chest Depth, Elbow Breadth, Measurement Techniques, Wrist Breadth

"Body breadth measurements are used for several research and clinical purposes. Body breadths are used in the determination of body types, for example, the Heath-Carter somatotyping technique (1967); in determining frame size for estimating desirable weight from standard stature-weight charts, and in estimating the potential for lean weight gains in various populations, for example, athletes and anorexics."

This chapter discusses recommended techniques, purposes, literature, and reliability for: biacromial, bi-iliac, bitrochanteric, ankle (bimalleolar), elbow, and wrist breadths, and chest breadth and depth.

## 1989 PUBLICATIONS

- 170 Gordon, Claire C., Thomas Churchill, Charles E. Clauser, Bruce Bradtmiller, John T. McConville, Ilse O. Tebbetts, and Robert A. Walker. 1988 ANTHROPOMETRIC SURVEY OF U.S. ARMY PERSONNEL: SUMMARY STATISTICS INTERIM REPORT. Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-89/027, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, March 1989. 336 pages.

**KEY WORDS:** Anthropometric Survey, Automated Headboard Device, Body Size, Female Anthropometry, Head, Head Measuring Device, Headboard, Male Anthropometry, Measurement Definitions, Measurement Techniques, Summary Statistics

Results of the 1987-1988 anthropometric survey of Army personnel are presented in this report in the form of summary statistics and percentile data. These anthropometric data are presented for a subset of personnel (1774 men and 2208 women) sampled to match the proportions of age categories and racial/ethnic groups found in the active duty Army of June, 1988. Dimensions included in this report include 132 standard measurements made in the course of the survey, 60 derived dimensions calculated largely by adding and subtracting standard measurement data, and 48 head and face dimensions reported in traditional linear terms but collected by means of an automated headboard designed to obtain three-dimensional data. Measurement descriptions, visual indices, and a glossary of terms are included to help identify and locate dimensions.  
[Abstract]

- 171 Paquette, Steven P. and Claire C. Gordon. DERIVATION OF AN EXTRA-LARGE PASGT HELMET. Technical Report NATICK/TR-88/066, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, July 1989. 84 pages.

**KEY WORDS:** Head, Headgear, Helmet Sizing

Analysis of data from more than 21,000 soldiers measured in U.S. military anthropometric surveys since 1966 indicates that 0.47% exceed the upper limits of fit for the size Large PASGT helmet in one or more head dimensions. Although this frequency is relatively low, it suggests that at least 3,650 individuals in the active duty Army may be disaccommodated by the current PASGT sizing system, and that a size Extra-Large helmet will be needed if all soldiers must be fit within the system.

Several alternative methods for deriving the dimensional attributes of an Extra-Large helmet are discussed in this report, and a 6.3 mm (0.25 in) radial expansion of the existing size Large headform is recommended for developing the size Extra-Large helmet. Radial expansion was chosen in order to maintain the current shape of the PASGT helmet headform and to minimize the added weight due to the helmet size increase. The proposed Extra-Large limits of fit will accommodate the largest known individuals from the 1988 anthropometric survey as well as all prior military surveys. [Abstract]

- 172 Gordon, Claire C., Bruce Bradtmiller, Thomas Churchill, Charles E. Clauser, John T. McConville, Ilse O. Tebbetts, and Robert A. Walker. 1988 ANTHROPOMETRIC SURVEY OF U.S. ARMY PERSONNEL: METHODS AND SUMMARY STATISTICS. Contract Report (Contract DAAK60-86-C-0128), Anthropology Research Project, Inc., Yellow Springs, Ohio. Technical Report NATICK/TR-89/044, U.S. Army Natick Research, Development and Engineering Center, Natick, MA, 1989. 652 pages.

**KEY WORDS:** Anthropometric Survey, Automated Headboard Device, Body Size, Female Anthropometry, Head, Head Measuring Device, Headboard, Male Anthropometry, Measurement Definitions, Measurement Techniques, Observer Error, Sampling Strategy, Summary Statistics

Results of the 1987-1988 anthropometric survey of Army personnel are presented in this report in the form of summary statistics, percentile data and frequency distributions. These anthropometric data are presented for a subset of personnel (1,774 men and 2,208 women) sampled to match the proportions of age categories and racial/ethnic groups found in the active duty Army of June 1988. Dimensions given in this report include 132 standard measurements made in the course of the survey, 60 derived dimensions calculated largely by adding and subtracting standard measurement data, and 48 head and face dimensions reported in traditional linear terms but collected by means of an automated headboard designed to obtain three-dimensional data. Measurement descriptions, visual indices, and a glossary of terms are included to help identify and locate dimensions. Also appearing in this report are descriptions of the procedures and techniques used in this survey. These include explanations of the complex sampling plan, computer editing procedures, and strategies for minimizing observer error. Tabular material in Appendices A and C are designed to help users understand various practical applications of the dimensional data, and to identify comparable data obtained in previous anthropometric surveys.

[Abstract]

### 1990 PUBLICATIONS

- 173 Greiner, Thomas M. A COMPARISON OF SECULAR CHANGE IN FOUR RACIAL/CULTURAL GROUPS. (Poster presented at the American Association of Physical Anthropologists meetings in Miami, FL. April 7, 1990.) Abstract in American Journal of Physical Anthropology Vol. 81, No. 2, 232, February 1990.

**KEY WORDS:** Body Size, Male Anthropometry, Racial Variation, Secular Trends

The 1988 Anthropometric Survey of U.S. Army personnel provides a data base that describes the body dimensions of over 5500 men. These data are combined with data on over 4000 men from the 1966 Anthropometric Survey to study rates of secular change of 22 dimensions in four racial/cultural groups: Whites, Blacks, Hispanics and Asian/Pacific Islanders.

Individuals are grouped by birth year into 12 five year cohorts, which span the years 1911 to 1970. Rates of secular change are calculated by (weighted least squares) regressing age adjusted values with respect to cohort.

Twenty-two plots present the relationships between birth year cohort and the anthropometric dimensions. Associated with each plot are the relevant regression equations, related statistics, and a statement of group similarity when appropriate. The analysis of covariance, testing for the equality of slopes, showed that Blacks and Asian/Pacific Islanders have statistically similar rates of change in 6 of the 22 dimensions. Conversely, White and Hispanics have equivalent rates of change for only three dimensions, although they have very similar rates in 14 more dimensions.

A discriminant analysis between surveys identifies dimensions that have undergone the most relative change. Generally, measurements related to soft tissue development, such as bicepoid breadth, are more highly correlated with discrimination than are skeletal measurements, such as head breadth. This pattern is consistent with the recent cultural emphasis on health and physical fitness.

Two groups have intriguing secular change patterns. First is the Asians/Pacific Islanders, whose secular changes were attributed to migration. This interpretation suggests that Asians/Pacific Islanders may be too broadly defined by the Army, and therefore by this study, to be used as a single racial/cultural category. Second, Blacks had the lowest rates of secular change, despite the facts that their changes were associated with soft tissue, as opposed to skeletal dimensions, and that the group is predominantly comprised of native born Americans. Similar patterns have been attributed to the relatively limited access of Blacks to resources in our society.

In general, statistically significant rates of change were detected in each group for every dimension, the exceptions being associated with the Asian/Pacific Islanders. Nevertheless, the biological importance of these changes is unclear. For all dimensions the magnitude of change was very small -- most were less than 1 cm per decade. The causes of these changes, inasmuch as they have been identified, are due to cultural processes. This indicates that biological forces play a diminished role in shaping the patterns of secular change. Therefore, it may be more appropriate to study secular change in groups that are culturally, rather than biologically, defined.

- 174 Cheverud, James, Claire C. Gordon, Robert A. Walker, Cashell Jacquish, Luci Kohn, Allen Moore, and Nyuta Yamashita. 1988 ANTHROPOMETRIC SURVEY OF US ARMY PERSONNEL: BIVARIATE FREQUENCY TABLES. Contract Report (Contract DAAK60-89-C-1006), Northwestern University, Evanston, IL. Technical Report NATICK/TR-90/031, Natick Research, Development and Engineering Center, Natick, MA, May 1990. 286 pages.

KEY WORDS: Anthropometric Survey, Bivariate Tables, Clothing Sizing, Female Anthropometry, Human Engineering, Male Anthropometry, Work Station Design

In this report, bivariate frequency tables based on data from the 1988 Anthropometric Survey of U.S. Army Personnel are presented to facilitate the use of these data by designers of clothing, equipment, and workspaces which Army personnel will wear or use. For each pair of dimensions a bivariate frequency table is presented first for males and females combined, then for males and females separately. [Abstract]

- 175 Cheverud, James, Claire C. Gordon, Robert A. Walker, Cashell Jacquish, Luci Kohn, Allen Moore, Nyuta Yamashita. 1988 **ANTHROPOMETRIC SURVEY OF US ARMY PERSONNEL: CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS.** Contract Report (Contract DAAK60-89-C-1006), Northwestern University, Evanston, IL. Technical Report NATICK/TR-90/032-036, Natick Research, Development and Engineering Center, Natick, MA, May 1990.

1988 Anthropometric Survey of US Army Personnel: Regression Equations and Correlation Coefficients appears in five parts, as follows.

**Part 1: Statistical Techniques, Landmark, and Measurement Definitions** (pp. 1-51), NATICK/TR-90/032;

**KEY WORDS:** Anthropometric Survey, Mathematical Methods, Measurement Definitions

**Part 2: Simple and Partial Correlation Tables — Male** (pp. 52-312), NATICK/TR-90/033;

**KEY WORDS:** Anthropometric Survey, Correlation Coefficients, Male Anthropometry

**Part 3: Simple and Partial Correlation Tables — Female** (pp. 313-572), NATICK/TR-90/034;

**KEY WORDS:** Anthropometric Survey, Correlation Coefficients, Female Anthropometry

**Part 4: Bivariate Regression Tables** (pp. 573-853), NATICK/TR-90/035;

**KEY WORDS:** Anthropometric Survey, Bivariate Tables, Correlation Coefficients, Regression Analysis

**Part 5: Stepwise and Standard Multiple Regression Tables** (pp. 854-984), NATICK/TR-90/036.

**KEY WORDS:** Anthropometric Survey, Correlation Coefficients,

In this five-part series of reports are tabulated the statistical relationships among anthropometric measurements so that designers of Army materiel systems will be able to utilize the data in improving the man-materiel interface. The kinds of statistical relationships tabulated include simple correlations, partial correlations, bivariate regressions and multiple regressions. The simple correlations, partial correlations, and bivariate regressions are among all pairs of characters. Four sets of partial correlations are included, partialling out: stature only; weight

only; stature and weight simultaneously; and stature, weight, and age simultaneously. Standard multiple regressions include specific anthropometric dimensions regressed on standard pairs of measurements. Stepwise multiple regressions were also calculated for each anthropometric dimension using the first five independent variables selected in the stepwise procedure. All analyses were performed separately for males and females and are reported separately in the tables.

- 176 Paquette, Steven P. HUMAN AND ANALOGUE MODELS FOR COMPUTER-AIDED DESIGN AND ENGINEERING APPLICATIONS. Technical Report NATICK/TR-90/054, Natick Research, Development and Engineering Center, Natick, MA, November 1990.

KEY WORDS: Anthropometry, Biomechanics, Computer Graphics, Computer-Aided Design, Enfleshment, Ergonomics, Man Machine Systems, Models, Skeletal Link System, Software, Strength, Visibility

A review of six computerized human analogue models (SAMMIE, COMBIMAN, CREW CHIEF, CAR, JACK, and SAFEWORK) was conducted to identify the state-of-the-art in ergonomic modeling software. All of the models included here demonstrate some utility as ergonomic design tools and were developed so that materiel designers and engineers can conduct preliminary human factors analysis prior to prototype construction. These human figure models vary widely with respect to primary function and analytical capabilities. However, they essentially fall within one or more of the following categories: anthropometric accommodation analysis, biomechanical/strength modeling, or human-machine interface analysis. This report includes the developmental background of each model, the hardware requirements, and the major functions provided by each system, e.g., reach/clearance analysis, vision analysis, strength modeling, and computer simulation. The underlying anthropometric databases that support model generation are also reviewed. In addition, the techniques used to construct the human figures in terms of skeletal link structure and geometric representation of body segment shape and volume are discussed. Finally, some challenges are presented that confront future refinement of human figure models. [Abstract]

- 177 Greiner, Thomas M. and Claire C. Gordon. AN ASSESSMENT OF LONG-TERM CHANGES IN ANTHROPOMETRIC DIMENSIONS: SECULAR TRENDS OF U.S. ARMY MALES. Technical Report NATICK/TR-91/006, Natick Research, Development and Engineering Center, Natick, MA, December 1990.

**KEY WORDS:** Anthropometry, Army Personnel, Demography, Dimensions, Male Anthropometry, Models, Racial Variation, Secular Trends, Sizes

Data from the most recent U.S. Army Anthropometric Survey provide a unique opportunity to assess long-term changes in body dimensions within the Army population. This report describes these secular trends for 22 body dimensions in four racial/cultural groups: Whites, Blacks, Hispanics and Asian/Pacific Islanders.

Individuals were grouped by birth year into 12 five-year cohorts, which span the years 1911 to 1970. Rates of change were calculated by regressing age-adjusted dimensions against cohort. Analyses of these relationships showed that almost all dimensions sustained statistically significant linear trends, the few exceptions being found within the Asian/Pacific Islanders group. Furthermore, except for the Asian/Pacific Islanders, the greatest relative rates of change were found in dimensions related to soft tissue development rather than skeletal dimensions. This pattern is consistent with the recent American cultural emphasis on health and physical fitness. The markedly different patterns seen in Asian/Pacific Islanders were best explained by immigration: they have experienced a linear increase in the proportion of foreign born members.

Finally, a method of applying these models to predict anthropometric dimensions of future Army populations is presented. The influence of demographic composition upon expected anthropometric distributions is demonstrated by predicting dimension values for six potential Army populations in the year 2023. The utility, and limitations, of these models for predicting future anthropometric dimensions are also discussed. [Abstract]

### 1991 PUBLICATIONS

- 178 Donelson, Sarah M. and Claire C. Gordon. 1988 Anthropometric Survey of U.S. Army Personnel: Pilot Summary Statistics. Technical Report NATICK/TR-91/040, Natick Research, Development and Engineering Center, Natick, MA, July 1991.

**KEY WORDS:** Anthropometric Survey, Body Size, Female Anthropometry, Male Anthropometry, Measurement Definitions, Measurement Techniques, Pilots, Sampling Strategy, Summary Statistics

Results of the 1988 anthropometric survey of U.S. Army pilots are presented in this report in the form of summary statistics and percentile data. These anthropometric data are presented for all male pilots measured during the survey and for a subset of the female data pool who were demographically matched for age and race to the June 1989 U.S. Army female pilot population. A total of 132 standard measurements, 60 derived dimensions, and 48 head and face dimensions are summarized in this report. Each dimension is fully described and visual indices are provided to facilitate practical application of the data.

- 179 Greiner, Thomas M. Hand Anthropometry of U.S. Army Personnel. Technical Report, Natick Research, Development and Engineering Center, Natick, MA, Fall 1991.

**KEY WORDS:** Anthropometry, Body Size, Demography, Hand, Hand Photobox, Measurement Definitions

This report presents the results of the analysis of data on the hand gathered during the 1987-1988 anthropometric survey of Army personnel. Data are presented in the form of summary statistics and percentile tables. In addition, correlations, regressions, analyses of variance and principal components for sex and racial groups, nonmetric trait frequencies, and observer error magnitudes are reported. These data summaries are presented for a subset of the actual data base (1003 men and 1304 women) that match the working data bases summarized in the Anthropometric Survey's Final Report. Therefore, the hand working data bases match the demographic characteristics of the June 1988 Army and are comprised of individuals that are in the Anthropometric survey's working data bases. The dimensions given in this report include 64 hand measurements that were obtained using a special photometric system. An additional 22 dimensions, obtained through direct measurement during the Anthropometric Survey, were added to the hand data base. Therefore, a total of 86 dimensions are presented in this report. Measurement descriptions, visual indices, and a glossary are included to aid readers in locating dimensions and in interpreting presentations.

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## APPENDIX I

### NON-NATICK PUBLICATIONS IN ARMY ANTHROPOLOGY/ANTHROPOMETRY

- A1 Nelson, H.W. and J.E. Leopardo. MINIMUM CUBIC DIMENSIONS FOR OPERATORS OF AN INTEGRATED FIRE-CONTROL SYSTEM. TM 22-56, Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, August 1956.

KEY WORDS: Anthropometric Measurements, Fire-Control System, Work Station Design

As referenced in the Human Engineering Laboratory's 1990 edition of Milestones, this document represents a compilation of data concerning the minimum dimensions for an integrated fire-control system.

- A2 Schane, W.P. and K.E. Slinde. SOME CREW SPACE MEASUREMENTS IN ARMY AIRCRAFT. United States Army Aeromedical Research Laboratory, Fort Rucker, Alabama, May 1966.

KEY WORDS: Aircrew, Anthropometry, Cockpit Design, Pilots

Measurements were made in the cockpits of every type of aircraft presently in the U.S. Army inventory, and in most prototype aircraft scheduled for delivery to the U.S. Army through FY 1970.

From these measurements it appears that a pilot of standing height greater than 76 inches or sitting height greater than 38 inches would be unable to comfortably and safely pilot many U.S. Army aircraft. This applied particularly to the aircraft used in both fixed- and rotary-wing pilot training. [Abstract]

- A3 Dobbins, D.A. and C.M. Kindick. ANTHROPOMETRY OF THE LATIN-AMERICAN ARMED FORCES (INTERIM REPORT). Research Report No. 10, U.S. Army Tropic Test Center, Fort Clayton, Canal Zone, May 1967.

KEY WORDS Aircrew, Anthropometric Survey, Body Build, Foreign Anthropometry, Latin-American Military, Male Anthropometry, Pilots, Racial Variation

The U.S. Army Tropic Test Center made anthropometric measurements on a sample of Latin-American military personnel in the Canal Zone from September 1965 to September 1966.

A total of 733 trainees were measured — 600 aircrew at the USAF Inter-American Air Force Academy and 133 Army personnel at the U.S. Army School of the Americas. Eighteen Latin-American countries are represented in the sample. The average age for the sample was 23 years, average height was 65.5 inches, and average weight 140 pounds.

Percentiles and ranges for 76 physical measurements are presented, including isometric strength and hand-grip measures. Reliability coefficients for strength measurements ranged from 0.73 to 0.87.

Comparisons with Thai and U.S. personnel showed that the Latin-American sample was intermediate between the two on most physical dimensions; however, the Latin-Americans were much closer in size to the Thai than to the U.S. military personnel.

Photographs illustrating various body builds are shown.

**A4 Schane, William P., Delvin E. Littell, and Charles G. Moultrie. SELECTED ANTHROPOMETRIC MEASUREMENTS OF 1,640 U.S. ARMY WARRANT OFFICER CANDIDATE FLIGHT TRAINEES. U.S. Army Aeromedical Research Laboratory, Fort Rucker, AL, February 1969.**

**KEY WORDS:** Aircrew, Anthropometric Survey, Aviators, Cockpit Design, Combat Vehicles, Human Engineering, Measurement Techniques, Pilots, Work Station Design

The results of nine anthropometric measurements made on 1,640 U.S. Army warrant officer candidates are presented. The nine measurements were selected as those which contribute most to aircrew workspace design in aircraft.

Comparisons of these data were made with similar measurements conducted upon flying personnel in five separate studies by other military services. [Abstract]

**A5 Dobbins, D.A. and C.M. Kindick. ANTHROPOMETRY OF THE LATIN-AMERICAN ARMED FORCES (FINAL REPORT). USATTC Report No. 7209902, U.S. Army Tropic Test Center, Fort Clayton, Canal Zone, August 1972.**

**KEY WORDS:** Anthropometric Survey, Blood Groups, Foreign Anthropometry, Geographical Variation, Latin-American Military, Pilots, Summary Statistics

The United States Army Tropic Test Center made anthropometric measurements of a sample of Latin-American enlisted military personnel in the Canal Zone from September 1965 to February 1970.

A total of 1,985 trainees were measured - 1952 aircrew at the USAF Inter-American Air Forces Academy and 133 Army personnel at the

U.S. Army School of the Americas. Fifteen Latin-American countries are represented in the sample. The average age for the sample was 23 years, average height was 5 feet 5 1/2 inches, and average weight was 141 pounds.

Percentile and ranges for 75 physical measurements are presented, including isometric strength and hand-grip measures. Country-by-country comparisons are also presented. In addition, 1,790 blood group types are presented by country.

These data represent the only known source of detailed anthropometric information on Latin-American military personnel.  
[Abstract]

A6 Kramer, R.R. A SIMULATION OF THE HUMAN SHOULDER. TM 15-75, Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, May 1975.

KEY WORDS: Ballistic Materials, Shoulder

As referenced in the Human Engineering Laboratory's 1990 edition of Milestones, this document presents a method for estimating the recoil force at the interface between the firer's shoulder and his weapon. The method involves simultaneous second order differential equations, whose coefficients have been determined by empirical fits. An example is given, which shows how the initial pitch-up and the recoil forces of a rocket launcher can be estimated.

A7 Cote, David O. and Aaron W. Schopper. ANTHROPOMETRIC COCKPIT COMPATIBILITY ASSESSMENT OF U.S. ARMY AIRCRAFT FOR LARGE AND SMALL PERSONNEL WEARING A COLD WEATHER, ARMORED VEST, CHEMICAL DEFENSE PROTECTIVE CLOTHING CONFIGURATION. United States Army Aeromedical Research Laboratory, Fort Rucker, Alabama, July 1984.

KEY WORDS: Anthropometry, Aviators, Cockpit Design, Helicopters, Stature

This sequel to an earlier report upon individuals wearing a warm weather uniform presents the results of an anthropometric cockpit compatibility evaluation conducted with individuals wearing a "worst-case" tactical clothing configuration; i.e., a combination of cold weather, armored vest, and chemical defense protective clothing. Subjects corresponding in stature to the uppermost and lowermost 5th percentiles of the Army male population were placed in the cockpits of all current U.S. Army helicopters (except AH-64) and fixed-wing aircraft, and requested to demonstrate critical operational reaches with the shoulder harness unlocked.

As in the previous report, a relatively wide range of upper- and lower-body reach requirements were encountered. With the exception of a very large requirement associated with the TH-55 helicopter, upper-body reach requirements, as measured by total arm reach ("span"), ranged from 147-173 cm. For crotch height, the measure of leg-reach capability found most efficient, the range was 69-78 cm. Four aircraft could not accommodate the individual with the tallest sitting height (102 cm).

New and more extensive levels of previously encountered problems were evidenced regarding the ability of subjects to achieve full range of cyclic, stick, and yoke travel. Restraint harness and lap belt difficulties were also observed. [Abstract]

A8 Schopper, Aaron W. and George R. Mastroianni. **HELICOPTER-REFERENCED SINGLE CONTROL, CENTER-POSITION FORCE EXERTION CAPABILITIES OF MALES AND FEMALES.** U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, August 1985.

**KEY WORDS:** Aviators, Force, Helicopters, Work Station Design

In response to the need for reevaluation of anthropometric criteria contained in the U.S. Army medical standards for flying duty, an assessment was made of helicopter-control-referenced force exertion capabilities of a sample of Army males and females. Males (N=74) ranged from 159 cm through 196 cm in stature; females (N=66) ranged from 152 cm through 183 cm. The force-exertion data were compared to values cited in MIL-H-8501A as upper force limits for the design of helicopter controls. The focuses of the analyses were upon the force exertion capabilities of individuals 167 cm (65.7 inches) and below in stature since, by virtue of their relatively small size, they represent the portion of the population which are most apt to evidence inability to exert forces which equal or exceed control force design limits. The comparison revealed that, overall, the presently existing limits (published in 1961) for other-than-the normal operational flight envelope exceeded the force exertion capabilities of 10 percent of the 39 small males evaluated and 27 percent of 56 [sic] females evaluated. Most failures to achieve existing or proposed control force design limits occurred because of inability to attain criterion-level exertions in the downward direction on the collective. Predicated upon the force exertion data from the small individuals of this study, various combinations of specific control force design limits were evaluated to develop estimations of overall "set-wise" failure rates likely to be encountered during possible future strength testing/screening. Because testing entailed no incentive for participation and involved multiple exertions within the session, it is anticipated that the percentage of failures encountered represent an overestimation of the failure-rate which would likely be encountered in the future while testing the strength capability of short individuals actually seeking to become or remain as aviators. [Abstract]

A9 Cote, David O. and Aaron W. Schopper. SEATED EYE POSITIONS AND ANTHROPOMETRIC EXTREMES OF AVIATORS. United States Army Aeromedical Research Laboratory, Fort Rucker, Alabama, May 1986.

KEY WORDS: Anthropometry, Aviators, Helicopters, Visual Field

Seated eye positions of personnel in the 1st to 5th percentile range and the 95th to 99th percentile range for male stature were examined in six U.S. Army helicopters to determine if their seated eye positions were significantly different from those of instructor pilots. In addition, the zero azimuth, outside-the-cockpit field-of-view of anthropometrically extreme personnel and instructor pilots, was measured. Large differences in viewing angles were also observed in all aircraft. However, in the case of personnel in the 1st to 5th percentile range for male stature, the differences were to their advantage. In the case of personnel in the 95th to 99th percentile for male stature, field-of-view was considerably decreased in some aircraft. Further study is needed to determine what effects the reduced field-of-view for tall personnel may have on flying performance. [Abstract]

A10 Schopper, Aaron W. PROPORTIONS OF OVERALL U.S. ARMY MALE AND FEMALE POPULATIONS ELIGIBLE FOR FLYING DUTY: IMPACT OF LINEAR ANTHROPOMETRIC SCREENING REQUIREMENTS. U.S. Army Aeromedical Research Laboratory, Fort Rucker, Alabama, August 1986.

KEY WORDS: Anthropometry, Aviators, Flight Physicals

To ascertain the impact on U.S. Army male and female population bases, the dimensions cited in two previously reported studies on the anthropometric arm-reach, leg-reach, and sitting height cockpit compatibility-related constraints inherent in each existing U.S. Army fixed-wing and rotary-wing aircraft (except the AH-64 Apache) were transformed into percentile equivalents. The percentage of the male and female populations excluded on each dimension was cited for each aircraft. Additionally, the percent of exclusion was calculated for each aircraft based upon the simultaneous con-joint consideration of all three measures to determine the anticipated percent-of-exclusion which would result when applicants were actually evaluated during flight physicals (wherein a failure to meet the standard on any single dimension would have the same impact as failing to meet all three). The data which resulted were considered vis-a-vis such factors as aircraft-specific aviator demand, aircraft mission versus DA policy on utilization of females in combat roles, warm-weather training versus cold-weather/armor plate/chemical defense clothing configurations,

physical strength-related issues, extent of heterogeneity in the reach-related demands encountered among the various types of aircraft evaluated, and single-criteria versus aircraft-specific criteria. The recommendations proposed a single set of linear anthropometric initial entry screening criteria which were compatible with the training helicopter (TH-55), the Army's utility helicopters (UH-1 and UH-60), and two of the Army's fixed-wing aircraft (C-12 and OV-1). Collectively, these initial-entry screen criteria were compatible with 60 percent of the Army's rotary-wing aircraft and 55 percent of the Army's fixed-wing aircraft. Aircraft-specific linear anthropometric screening criteria were recommended for the remaining rotary-wing (AH-1, CH-47, OH-6, and OH-58) and fixed-wing (T-42, U-8, and U-21) aircraft. [Abstract]

All Hinkes, Madeleine J. ANTHROPOLOGY MEETS AVIATION PATHOLOGY. Paper presented at the 39th Annual Meeting of the American Academy of Forensic Sciences, San Diego, CA, 1987.

KEY WORDS: Aviation Disasters, Commingled Remains, Forensic Anthropology, Human Identification

On 12-12-85, a military charter DC-8 carrying home members of the U.S. Sinai Peacekeeping Force to their home base at Ft. Campbell, KY, crashed shortly after takeoff from an intermediate stop in Gander, Newfoundland. All 256 aboard were killed, making this the deadliest U.S. military accident in history. The remains were transported to the port mortuary at Dover AFB for autopsy and identification.

Three weeks into the investigation, the services of a physical anthropologist were requested, to help with particularly problematic cases: incinerated and dismembered remains; relatively intact remains for which no positive identification could be made due to lack of antemortem records. Age, sex, race, stature, and body build were assessed from the remains; and distinguishing features were noted. Other tasks falling to the anthropologist included identifying nearly 300 severed and charred limb and body portions recovered on site searches, verifying body part inventories, and sorting commingled remains.

The investigation team succeeded in identifying remains of 8 crewmembers and all 248 manifested passengers. The unique contribution of anthropology necessitates that a forensic anthropologist be included in all phases of casualty resolution from recovery and initial processing to final evaluation, rather than being summoned as a last resort. [Abstract]

A12 Miller, Peter S. **WHEN YOU DON'T KNOW FOR SURE: AN ANTHROPOLOGICAL IDENTIFICATION RATING SYSTEM.** Paper presented at the 39th Annual Meeting of the American Academy of Forensic Sciences, San Diego, CA, 1987.

**KEY WORDS:** Commingled Remains, Forensic Anthropology, Human Identification

The USA Central Identification Laboratory has cases where skeletal remains are badly weathered and fragmentary, where remains lack teeth or distinguishing dental patterns, or there are no unique skeletal traits. In some situations there are either no X-rays, the date of last medical and dental examination was many years earlier than the time of presumed death, or remains show signs of substantive modification due to starvation, severe deprivation, or massive injury. Certainty in establishing identity in these cases is unlikely. A rating from zero to plus five is proposed to scale such cases from mismatch through positive identification. Case studies are presented to illustrate the use of the rating system. [Abstract]

A13 Harry G. Armstrong Aerospace Medical Research Laboratory, Naval Aerospace Medical Research Laboratory, Naval Air Development Center, Naval Biodynamics Laboratory, U.S. Air Force School of Aerospace Medicine, and U.S. Army Aeromedical Research Laboratory. **ANTHROPOMETRY AND MASS DISTRIBUTION FOR HUMAN ANALOGUES, VOLUME I: MILITARY MALE AVIATORS.** AAMRL TR-88-10, NAMRL-1334, NADC-88036-60, NERL 87R003, USAF-SAM-TR-88-6, March 1988.

**KEY WORDS:** Anthropometry, Dummies

Anthropometric and mass distribution data for use in constructing three-dimensional human analogues--mathematical models or test dummies--are presented in this report. Included here are body dimensions, joint locations, and mass distribution properties appropriate for modeling the small, midsize, and large male aviator of the 1980s. The data were derived from; (1) 139 body dimensions of standing and seated males obtained by traditional anthropometric methods; (2) mass distribution data for body segments obtained by stereophotographic techniques; and (3) skeletal joint centers obtained by estimation. The anthropometric data, generated from multiple regressions on stature and weight, are suitable as the basis for models to be used in testing responses to impact and other mechanical forces; they are not recommended for other purposes such as the sizing of clothing and personal protective equipment, or workspace design. [Abstract]

A14 Hinkes, Madeleine J. **HUMAN IDENTIFICATION IN A FAR OFF PLACE.** Paper presented at the 41st Annual Meeting of the American Academy of Forensic Sciences, Las Vegas, NV, 1989.

**KEY WORDS:** Aviation Disasters, Burma, Forensic Anthropology, Human Identification

Identification of disaster victims is difficult under the best of circumstances, but a disaster occurring in a Third World nation brings an additional set of problems in terms of adaptability and diplomacy. An example is the October 1987 crash of a Burmese plane near Pagan, Burma, which killed 49 persons from 8 countries. When the American Embassy requested forensic assistance in verifying the identifications assigned by Burmese officials, a U.S. team from CILHI and the FBI was sent.

Before the team arrived and before the representatives of all countries involved could be coordinated, one had given permission to begin cremation of the remains of its citizens. This caused great concern when it was later found that many of these preliminary identifications were erroneous. Most other problems encountered involved climate, logistics, and politics.

Despite these obstacles, 32 of 36 non-Burmese were identified by the U.S. team, using a combination of dental, fingerprint, and anthropological evidence. This experience reinforces the opinion that there is much more to forensic anthropology than just bones. Thus, training programs should emphasize a broad range of skills and experience to enable anthropologists to fill unconventional slots on an identification team and to adapt to any working conditions.  
[Abstract]

A15 Hinkes, Madeleine J. **THE ROLE OF FORENSIC ANTHROPOLOGY IN MASS DISASTER RESOLUTION.** Aviation, Space, and Environmental Medicine, July 1989.

**KEY WORDS:** Aviation Disasters, Commingled Remains, Forensic Anthropology, Human Identification, Pubic Symphysis

On December 12, 1985, a military charter DC-8 crashed shortly after takeoff at Gander, Newfoundland, Canada. All 256 aboard were killed, making this the deadliest U.S. military aircraft accident in history. The investigation team (consisting of forensic pathologists, odontologists, radiologists, anthropologists, graves registration personnel, and systems engineers) succeeded in identifying the remains

of all 248 manifested passengers and 8 crewmembers. The unique contribution of anthropology necessitates that a forensic anthropologist be included in all phases of casualty resolution from recovery and initial processing to final evaluation, rather than being summoned as a last resort. This approach would yield immediate information on "unknowns" and would eliminate subsequent duplication of effort. [Abstract]